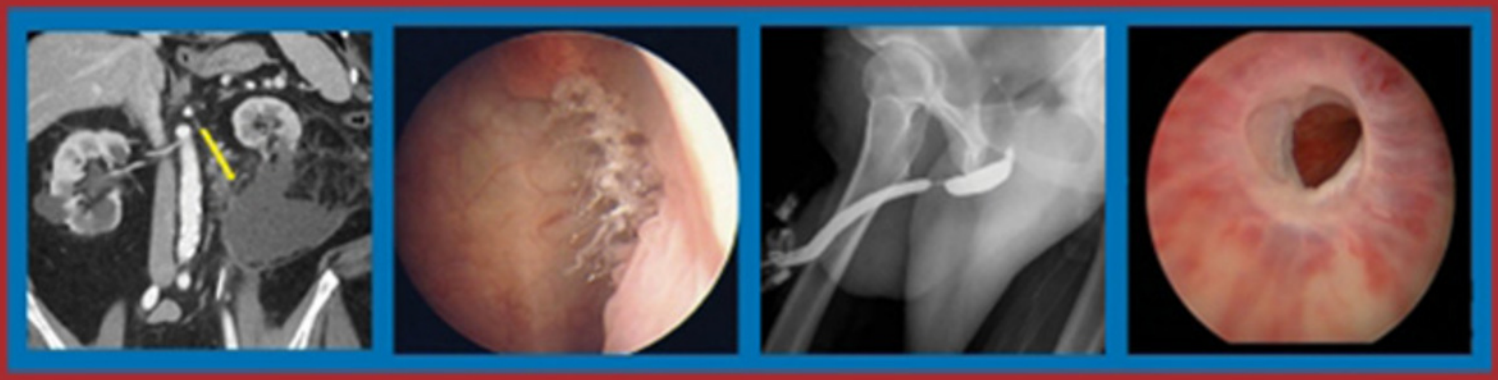
TANEJA'S COMPLICATIONS of UROLOGIC SURGERY

Diagnosis, Prevention, and Management

FIFTH EDITION



Samir S. Taneja
Ojas Shah

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Edinburgh London New York Oxford Philadelphia St Louis Sydney 2018

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First edition 1976
Second edition 1990
Third edition 2001
Fourth edition 2010
Fifth edition 2018

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ISBN: 978-0-323-39242-6
e-ISBN: 978-0-323-392488

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Printed in China

Last digit is the print number: 9 8 7 6 5 4 3 2 1

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Preface

Surgery is never perfect, but that should not stop a surgeon's pursuit of perfection.

In many ways, this is the nature of a surgical career – continually refining one's approach and technique through observation, trial and error, and experience. In doing so, excellent outcomes can be achieved with any operation, and when complications arise, early recognition and proper management can allow expeditious recovery.

Optimizing surgical outcomes can be viewed as a lifelong exercise for the surgeon, but for the individual patient, only one outcome matters. Although it is easy for the busy surgeon to consider any operation as routine, it is essential to view each procedure, no matter how routine, as important and carrying potentially life-altering results for the patient. The balance between confidence and neglect is narrow for surgeons, and humility serves the surgeon well in recognizing that no matter how good or experienced the surgeon is, complications are inevitable. Even the operation that appears to go well, in an otherwise healthy patient, can result in complication.

When planning an operation, consideration of unique host factors predisposing the patient to complication is essential. With increasing experience, the surgeon will recognize those cases in which surgery is ill advised. Too often, early in a surgeon's career, complications arise through poor patient selection or preparation, or inadequate attention to risk factors in planning the procedure. Patients with underlying cardiopulmonary compromise, diabetes, coagulopathy, or morbid obesity should be considered at highest risk of complications delaying or preventing recovery. In particular, obese patients carry both the risk of complications due to underlying medical disease and those related to the increased technical difficulty of the procedure. Likewise, re-operative procedures can carry unique technical challenges and risks. When starting out, recognition of these challenges, and consideration of referral to a surgeon experienced with those types of patients, can save a great deal of anguish for surgeon and patient.

While caution is essential, surgeons must also be willing to take on challenging cases when patients are in absolute need of care. Careful preoperative assessment, operative planning, consultation when appropriate, and adherence to fundamental surgical principles allow the best opportunity for a good outcome. When confronted with a complication, the surgeon must refrain from efforts to minimize the problem and use a judicious approach to determine the right course.

First and foremost, complications take a tremendous emotional and physical toll on our patients, and surgeons must remember this when confronted with a complication. For the patient, the process of surgery is one in which control is given completely to the surgeon. The uncertainty of outcome, the loss of control, and the fear of mortality are tremendously stressful for the patient even in the setting of an uncomplicated surgery. When complications arise, these stresses are magnified and patients and their families are often confused, depressed, or angry. Demonstration of sincere empathy and sympathy are critically important. Careful, calm, and comprehensive communication are essential to enable them to understand the nature of the complication, its probable causes and outcomes, and concerns going forward. Specific benchmarks for improvement can allow the patient and family a structured process to mentally cope with the situation. Patients with complications often fear the surgeon will abandon them, and reassurance can go a long way toward maintaining a good relationship.

Physical concerns in the setting of complications relate to the patient's ability to tolerate the stresses and the relative risk of prolonged hospitalization. In patients with preexisting comorbid conditions, careful attention to management of underlying disease processes, particularly those influencing recovery, will help in avoiding secondary complications. Maintaining nutrition, preventing infection, and carefully monitoring fluids and electrolytes are fundamental surgical principles that directly affect recovery from most procedures, but that can easily be forgotten in the heat of stressful complication. Although not all patients recover from complications, the surgeon's primary goal must be to optimize the patient's condition to maximize the patient's odds of recovery.

The balance between action and inaction is a difficult one for surgeons. An underlying desire to make a complication go away often leads to a hasty decision to act quickly through reoperation or intervention. Although sometimes indicated, quick decisions to intervene often result in worsening of the problem or development of secondary complications. At the time of complication, careful diagnostic evaluation to fully understand its nature and extent are critically important before any action is taken. Although stressful for both the patient and the surgeon, sometimes waiting it out is the best course of action.

Over the years, *Complications of Urologic Surgery: Diagnosis, Prevention, and Management* has become a text popular among those in training and those in practice, largely due to its ability to provide information relevant to day-to-day practice. It has been translated in multiple languages, creating access for urologists around the world. In this fifth edition of the text, we have expanded the title to include "Diagnosis", recognizing that the early identification of complications is as important as their management. We have additionally made the content more contemporary, by removing references to operations rarely performed in modern practice, and adding a number of chapters dedicated to complications unique to the emerging standard of minimally invasive surgery and specific procedures commonly employing laparoscopy or robotic-assisted laparoscopy. Recognizing that robotic-assisted surgery is growing in utilization, but remains underutilized, due to cost, around the world, we have retained detailed discussion of

the conventional procedures commonly performed in urologic practice, expanding upon the diversity of authors to allow a broad perspective to approach. Finally, for trainees, we have added a new study guide with questions and case presentations to test knowledge and inspire questions in mastering the content of the text. It is our sincere hope that the text will remain a popular, frequently utilized source of information for practicing urologists around the globe.

Samir S. Taneja, MD

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We would like to dedicate this book to the many who have so greatly influenced our lives and careers.

To our parents, Vidya Sagar and Sudesh Taneja, and Dinker and Aruna Shah, for setting an example and encouraging us to relentlessly pursue excellence in our education and professional life.

To our mentors, Jean deKernion, Robert Smith, Richard Ehrlich, Dean Assimos, and Herbert Lepor, for teaching us the science and craft of surgery and supporting us in failure or success.

To our families, Uma, Sorab, and Sabina Taneja, and Rupa, Siena, Devon, and Mira Shah, for their patience, love and support in allowing us to pursue the distractions of our academic life.

And, most importantly, to our many patients whose care has taught us so much, whose needs have inspired persistence and innovation, and whose gratitude has motivated us to carry on each day.

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SECTION I

Preoperative Assessment and Perioperative Management

1 Impact of Host Factors and Comorbid Conditions

KATHLEEN F. MCGINLEY and STEPHEN J. FREEDLAND

CHAPTER OUTLINE

Obesity
Obesity and Urologic Malignant Diseases
Prostate Cancer
Kidney Cancer
Bladder Cancer
Obesity and Benign Urologic Conditions
Benign Prostatic Hyperplasia and Lower Urinary Tract Symptoms
Erectile Dysfunction
Stress Urinary Incontinence
Urolithiasis
Malnutrition
Nutritional Status Assessment
Preoperative Management of Malnutrition
Infection and Urosepsis
Quantifying Comorbidity
Conclusion
Chapter 1 Questions and Answers

KEY POINTS

1. With increasing life expectancy in the general population, the prevalence of comorbid conditions such as obesity, heart disease, and diabetes has increased to alarming proportions.
2. Awareness of comorbidities allows the urologist to institute the proper measures to control preexisting diseases to optimize the overall health status of the individual patient, maximize the likelihood of a good outcome, and minimize the risk of a complication.
3. Obesity can directly influence surgical outcome because of certain proposed biologic linkages with urologic malignant diseases.
4. Nutritional status is a key clinical parameter demanding thorough evaluation in the surgical patient to prevent nutrition-related complications.
5. Given that certain host factors predispose the urologic patient to complicated infection, it is necessary to determine the need for antimicrobial prophylaxis preoperatively and to prevent the occurrence of systemic septicemia.

Every urologist would prefer that any patient who has a consultation for a urologic disease would be solely afflicted with the disease for which he or she seeks medical attention, that every surgical patient would be healthy enough to tolerate the proposed surgical intervention to treat the condition, and that complications would occur with only miniscule probability. Unfortunately, this situation is far removed from reality and certainly is becoming less common in current clinical practice in which medical histories, physical examinations, preoperative laboratory examinations, and imaging scans are likely to reveal coexisting medical problems in the urologic patient.

In the present era, with life expectancy ever increasing, the prevalence of comorbid conditions such as obesity, heart disease, and diabetes, which affect urologic diseases and their clinical outcome following management, has congruently reached alarming proportions in the general population. Whether driven by improved medical science, rapid technologic advancement, or an effect of natural selection, men and women are living longer (Fig. 1.1). The medical community recognizes special considerations for elderly patients, and most of these considerations are brought about by medical conditions that are diagnosed in later life and progress with advancing age. In urologic disease entities such as erectile dysfunction in men, pelvic floor disorders in women, and urologic malignant diseases such as prostate and bladder cancer, the predisposition and clinical effects related to advanced age have direct biologic implications for the urologic condition. Moreover, because most of these disease entities are diagnosed in the more mature stages of life, the probability of preexisting medical conditions in these patients at the time of consultation is high.

Notwithstanding the effect of age on comorbid medical conditions in the urologic patient, the past decades have also seen a dramatic rise in the prevalence of disease entities closely linked to harmful lifestyle choices such as smoking and alcohol consumption, unhealthy diets, lack of physical activity, and intravenous drug abuse. These lifestyle choices adversely affect patients of all ages who may seek urologic consultation and who may present with detrimental comorbidities such as childhood obesity, juvenile diabetes, chronic obstructive pulmonary disease, liver disease, and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS).

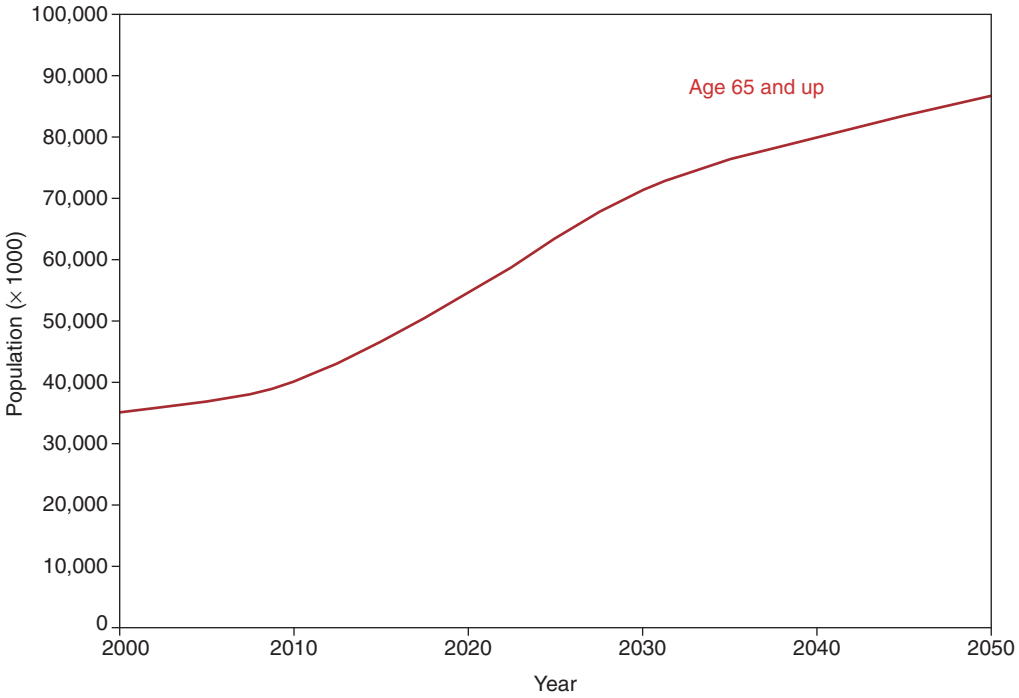


Figure 1.1 Projected population of the United States for adults ≥65 years old (2000–2050). Based on data from the United States Census Bureau (http://www.census.gov/ipc/www/usinterimproj/).

Although biologic links to known urologic diseases may be less apparent, the overall outcome and incidence of complications following surgical intervention are directly affected by coexisting health problems. Indeed, assessing the urologic patient for preexisting comorbidities is of critical importance because host factors play an important role in postoperative complications. Awareness of comorbidities allows the urologist to institute the proper measures to control preexisting diseases to optimize the overall health status of the individual patient, maximize the likelihood of a good outcome, and minimize the risk of a complication. The urologist also can assess the need for ancillary examinations for a more comprehensive evaluation of comorbid conditions more accurately and can determine the need for intraoperative monitoring and specialized intensive postsurgical care. More importantly, comprehensive knowledge of all concurrent illnesses in the urologic patient aids the urologist in deciding whether surgical intervention is the optimal treatment option or whether conservative management may be the best therapeutic alternative.

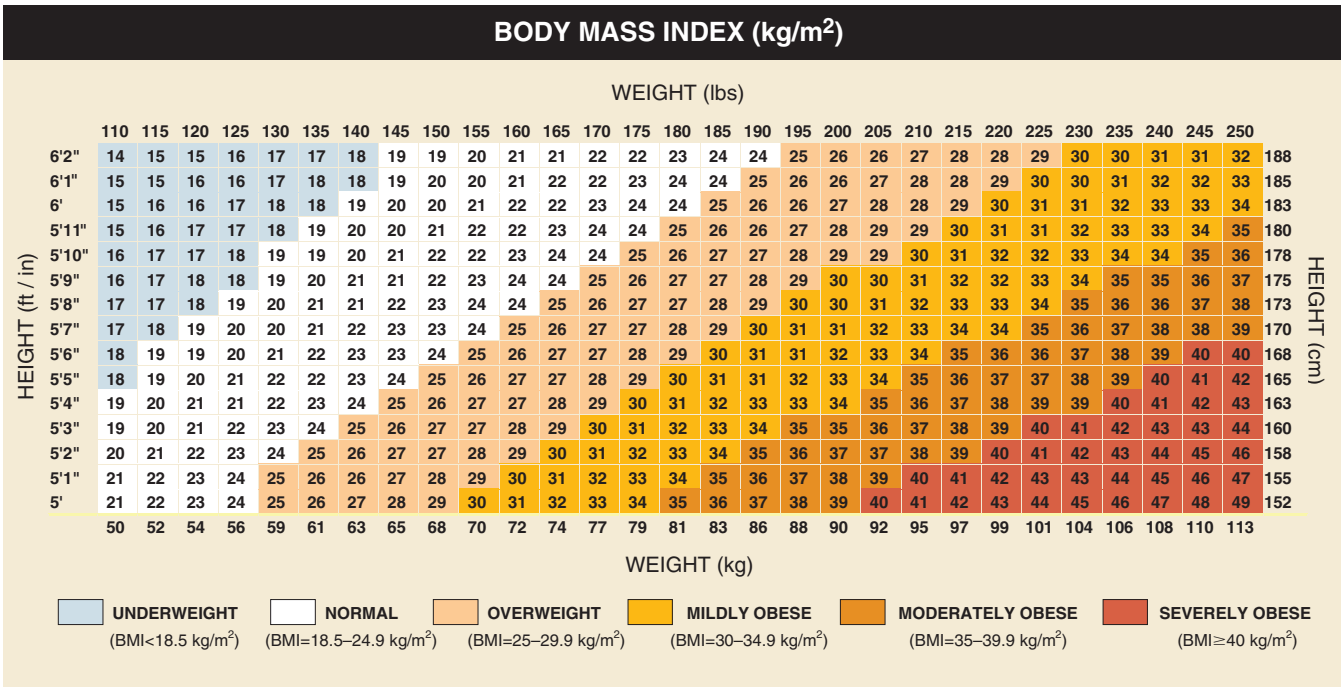
To serve as an introduction to the succeeding chapters in this section, we tackle host factors that significantly affect the occurrence of nonurologic complications following urologic surgery. We provide an overview of comorbidities in the urologic patient and highlight current prevalent disease entities that influence outcome following definitive surgical management. Comorbidities to which whole chapters are devoted, such as those pertaining to cardiovascular, pulmonary, hematologic, and anesthetic complications, are discussed only briefly here, to leave room for a more detailed discussion of topics of special interest such as obesity that are of major interest in the field of contemporary urology. We also provide insight into clinical tools such as useful comorbidity indices and scoring systems that aim to quantify the severity of comorbidities and predict posttreatment morbidity and mortality.

Obesity

The importance of nutritional status to surgical outcomes and the deleterious effects of obesity are of significant interest in the field of urology. Interest has centered on obesity for two main reasons: First, the prevalence of obesity has been growing at epidemic proportions worldwide,[1] and second scientific evidence suggests a relationship between obesity and multiple urologic conditions including benign prostatic hyperplasia (BPH),[2] urologic malignant diseases, incontinence, erectile dysfunction, and stone disease, to name a few.[3]

Most of the leading causes of death in the United States are linked to obesity, including heart disease, cancer, stroke, and diabetes.[4] Viewed as a growing national health crisis, obesity is the second leading cause of preventable death;[5] obesity not only results in a potentially avoidable toll in human lives but also incurs a substantial cost in health expenditure for the country.[6] Affecting over one-third of all adults in the United States,[7] obesity is further associated with various comorbidities, such as hypertension, sleep apnea, cholecystolithiasis, osteoarthritis, and depression, that may aggravate the overall health status of the overweight or obese patient and may contribute to surgical complications.[8] Childhood obesity is also on the rise and could have undesirable consequences for children and adolescents undergoing pediatric urologic procedures.[9]

Obesity is defined as an excess accumulation of adipose tissue in the body; however, functionally, *overweight* and *obese* are labels used to denote ranges of weight that are in



HEIGHT (ft / in)	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250	HEIGHT (cm)
6'2"	14	15	15	16	17	17	18	19	19	20	21	21	22	22	23	24	24	25	26	26	27	28	28	29	30	30	31	31	32	188
6'1"	15	15	16	16	17	18	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	28	29	30	30	31	32	32	33	185
6'	15	16	16	17	18	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	28	29	30	31	31	32	33	33	34	183
5'11"	15	16	17	17	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	29	29	30	31	31	32	33	33	34	35	180
5'10"	16	17	17	18	19	19	20	21	22	22	23	24	24	25	26	27	27	28	29	29	30	31	32	32	33	34	34	35	36	178
5'9"	16	17	18	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	30	31	32	32	33	34	35	35	36	37	175
5'8"	17	17	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	30	31	32	33	33	34	35	36	36	37	38	173
5'7"	17	18	19	20	20	21	22	23	23	24	25	26	27	27	28	29	30	31	31	32	33	34	34	35	36	37	38	38	39	170
5'6"	18	19	19	20	21	22	23	23	24	25	26	27	27	28	29	30	31	31	32	33	34	35	36	36	37	38	39	40	40	168
5'5"	18	19	20	21	22	22	23	24	25	26	27	27	28	29	30	31	31	32	33	34	35	36	37	37	38	39	40	41	42	165
5'4"	19	20	21	21	22	23	24	25	26	27	27	28	29	30	31	32	33	33	34	35	36	37	38	39	39	40	41	42	43	163
5'3"	19	20	21	22	23	24	25	26	27	27	28	29	30	31	32	33	34	35	35	36	37	38	39	40	41	42	43	43	44	160
5'2"	20	21	22	23	24	25	26	27	27	28	29	30	31	32	33	34	35	36	37	37	38	39	40	41	42	43	44	45	46	158
5'1"	21	22	23	24	25	26	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	43	44	45	46	47	155
5'	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	152
WEIGHT (kg)	50	52	54	56	59	61	63	65	68	70	72	74	77	79	81	83	86	88	90	92	95	97	99	101	104	106	108	110	113	

Figure 1.2 Estimates of body mass index using measured height and weight.

excess of what is generally considered healthy for the given height of a person. Because of its simplicity, body mass index (BMI) is a widely accepted method to assess for obesity. BMI is calculated by dividing the weight (in kilograms) of an individual by the height (in meters) squared.[10] Fig. 1.2 illustrates the standard weight status categories associated with BMI range for adults. Although other anthropometric measurements such as skinfold thickness and midarm circumference may be used for more accurate estimation of body fat, these measurements are not routinely recorded in clinical practice and are of limited availability for retrospective studies.[10]

Fat distribution may also be an important determinant of obesity because individuals with high BMI who have upper body fat distribution (android) have been shown to be at greater risk for comorbidities such as cardiovascular disease, cerebrovascular disease, and hypertension compared with men and women who have lower body fat distribution (gynecoid).[11] Newer studies found better accuracy in gauging obesity with the use of waist circumference and waist-to-hip ratios; however, these parameters are more cumbersome to measure compared with BMI.[12] *Central obesity* correlates with visceral fat accumulation in the abdomen and is diagnosed when the waist-to-hip ratio exceeds 1.0 in men and 0.9 in women. This condition is in contrast to *peripheral obesity*, in which fat accumulation occurs subcutaneously in the gluteofemoral region. However, the distinction is clinically important because central obesity imparts a significantly higher risk of insulin resistance and type 2 diabetes, blood lipid disorders, hypertension, and heart disease compared with peripheral obesity.[13]

The medical consequences of obesity result in part from increased secretion of pathogenic macromolecules from enlarged adipose cells. Increased release of fatty acids from fat cells that are stored in the liver or muscle results in the insulin-resistant state that is commonly seen in obesity. Diabetes ensues as the mounting insulin resistance overwhelms the secretory response of the pancreas.[14] Bioactive cytokines, particularly interleukin-6, released from adipocytes promote the proinflammatory state that is characteristic of obesity. Secretion of prothrombin activator inhibitor-1 from adipose cells, coupled with impaired endothelial function, plays a key role in the hypercoagulable state of obesity and ultimately increases the risk of cardiovascular disease, stroke, and hypertension in obesity. This prothrombotic state is further aggravated directly by increased estrogen levels and is complicated indirectly by decreased antiangiogenic cytokines such as adiponectin.[15] The overall effect of these multiple pathologic consequences of increased fat stores is the risk of shortened life expectancy.[16]

OBESITY AND UROLOGIC MALIGNANT DISEASES

Investigations since the late 1980s have sparked keen interest in the link between obesity and urologic cancer, especially for prostate adenocarcinoma and kidney cancer.[17] Investigators have hypothesized that diet and obesity affect the underlying biologic mechanisms that ultimately lead to carcinogenesis, including promotion of angiogenesis and mitogenesis, increased cellular proliferation, impairment of immune response, increased exposure to oxidative damage by free radicals, and promotion of a proinflammatory state.[18] Obesity can directly influence surgical outcome as a result of these proposed biologic linkages with urologic malignant diseases.

Prostate Cancer

Because obese men with prostate cancer have lower serum prostate-specific antigen (PSA) levels relative to men of normal weight,[19,20] and because physical assessment of the

prostate through digital rectal examination is hindered by adiposity, detection of prostate cancer among men with a high BMI may be delayed. Performing a transrectal ultrasound–guided biopsy to establish a tissue diagnosis of prostate cancer can also be more technically difficult in obese men, and because of prostatic enlargement, some cancers may be missed by undersampling.[19] After histopathologic confirmation of prostate cancer, the patient may opt for surgical treatment, but urologists may be reluctant to operate on morbidly obese patients for several reasons. The anesthetic risks pertaining to adequacy of ventilatory support and difficulty in fluid monitoring[21] are further complicated by the increased incidence of comorbid conditions such as hypertension, heart disease, stroke, and diabetes.[14]

If the urologist does perform surgery, adiposity can be a physical hindrance that may curtail adequate exposure of the surgical field, particularly when a retropubic approach is planned for access to the prostate. Among men undergoing an open retropubic prostatectomy, increasing BMI is associated with increasing operative time and increasing intraoperative blood loss.[22] For these reasons, some urologists have advocated that perineal prostatectomy or a robotic-assisted laparoscopic prostatectomy should be favored over an open retropubic approach for treatment of obese men with prostate cancer. However, a study by Fitzsimons and associates[23] suggested that both perineal and open retropubic approaches have comparable outcomes in terms of estimated blood loss and operative time for obese patients. In contrast, Ellimoottil and colleagues[24] found lower transfusion rates among 9108 obese men undergoing robotic-assisted laparoscopic prostatectomy versus an open retropubic approach; however, no difference in perioperative complications between the groups was identified. In a matched pair analysis including 255 patients, Beyer et al.[25] reported lower blood loss, transfusion rates, and fewer 30-day complications among obese men undergoing a robotic-assisted laparoscopic prostatectomy as compared to those undergoing an open retropubic prostatectomy.

Beyond technical issues, obesity may also influence the oncologic outcome among men undergoing radical prostatectomy. First, earlier studies found an increased incidence of positive surgical margins and capsular incision among men with higher BMIs.[26,27] Similarly, men with higher BMIs present with higher-grade tumors and more advance pathologic stages of disease.[28] On postsurgical follow-up, men with an elevated BMI ($\geq 30\ kg/m^2$) are at significantly increased risk of biochemical recurrence relative to men with a lower BMI, as denoted by an elevated postoperative PSA test result (>0.2 ng/mL or two values at 0.2 ng/mL).[26,29,30] More ominously, increased body weight was found to be associated with an increased risk of death from prostate cancer in a large, prospectively studied population.[31] Thus, obesity may well exert a biologic effect on prostate cancer that promotes aggressiveness and disease progression. However, in terms of health-related quality of life after radical prostatectomy, prospective studies have so far failed to demonstrate large differences between mildly obese men and men of normal weight.[32–35] For a more detailed review of obesity and prostate cancer, we recommend the article by Allott and Freedland in *European Urology*.[36]

Kidney Cancer

Obesity, particularly in women, has been shown to be associated with renal cell carcinoma (RCC).[31,37] A high BMI was found to be a strong risk factor for RCC; several underlying mechanisms were suspected, including higher insulin and estrogen levels, hypertension, hypercholesterolemia, and impaired host immune response.[38] Boeing and colleagues[39] examined determinants such as smoking, diet, occupational hazards, beverage consumption, medications, and obesity in a case-control cohort of 277 patients with RCC and 286 matched controls and found that specific dietary patterns associated with obesity, such as consumption of fatty foods and meat products, may explain the higher incidence of RCC in industrialized countries relative to developing countries.[39] Indeed, in a large retrospective study involving 363,992 men, investigators from the National Institutes of Health found that obese men, especially those with a history of tobacco use and elevated systolic blood pressures, have an increased long-term risk for RCC.[40]

As in prostate cancer, open surgical procedures for RCC can be technically difficult in patients with severe adiposity. Thus, wide interest exists in prescribing minimally invasive procedures for obese patients because these approaches have been found to be safe and effective for this subset of patients.[41–43] While BMI was found to be a significant risk factor for major postoperative complications in patients treated with laparoscopic surgery for RCC,[44] more recent literature evaluating robotic-assisted laparoscopic procedures have found no association between obesity and complication rates.[45,46] Finally, with regard to clinical outcome and cancer-specific mortality, overweight and obese patients have a higher risk of death from kidney cancer relative to patients of normal weight.[31]

Bladder Cancer

Compared with prostate and renal cancer, published reports of relationships between bladder cancer and obesity are scarce. In 1994, an epidemiologic study of 514 patients with bladder cancer found that beyond the well-known link with smoking, obesity was also a significant risk factor for bladder cancer.[47] This was substantiated in a recent case control study, in which patients with metabolic syndrome were at a twofold higher risk of bladder cancer.[48] However, a large prospective study of nearly 1 million people found no link between BMI and bladder cancer mortality.[31] With regard to diet, reports on the association between high fat intake and bladder cancer have been conflicting.[49,50]

With respect to surgical outcome for radical cystectomy, abundant reports show not only that obesity contributes to the technical challenge of the operation but also that higher BMI increases the risk of perioperative complications. In a retrospective analysis of 304 consecutive patients who underwent radical cystectomy and urinary diversion for bladder cancer, increased BMI was independently associated with higher estimated blood loss.[51] This finding was later confirmed in a cohort of 498 patients; the investigators concluded that, along with greater blood loss, an increased BMI was also independently associated with prolonged operative time and increased rate of complications.[52] In limited robotic cystectomy case series, increasing BMI

was not associated with prolonged operative times or increased blood loss, though it was associated with an increased rate of 90-day re-admission.[53,54]

OBESITY AND BENIGN UROLOGIC CONDITIONS

Several nonmalignant urologic conditions are also unfavorably affected by an increased BMI and morbid obesity.

Benign Prostatic Hyperplasia and Lower Urinary Tract Symptoms

Obesity is a known risk factor for lower urinary tract symptoms (LUTS) and BPH. Indeed, a large-scale, cross-sectional study from the Prostate Study Group of the Austrian Society for Urology found a link between BPH and obesity.[55] The relationship between obesity and LUTS was further confirmed in a report from Johns Hopkins University in Baltimore on 2797 men from the Third National Health and Nutrition Examination Survey.[56] In another confirmatory study, BPH was found to be associated with increased serum insulin levels and abdominal obesity as opposed to BMI itself.[57] The biologic link between obesity and BPH likely has its origin in the association of obesity with hyperinsulinemia and the status of insulin as a direct prostate growth factor.[58]

Erectile Dysfunction

Obesity, particularly central obesity, is a known predictor of erectile dysfunction in men.[59] Both atherosclerosis and diabetes mellitus, which are associated with obesity, play significant roles in the development of erectile dysfunction. Although the underlying cause for erectile dysfunction is thought to be multifactorial, investigators have suggested that obesity increases the risk of erectile dysfunction of vascular origin as a result of the development of chronic vascular disease.[60] Obesity is also known to increase the risk of diabetes. The microvascular complications characteristic of diabetes exert deleterious effects on erectile tissue similar to the pathologic features of diabetic nephropathy, retinopathy, and gastroparesis.[61] Furthermore, weight loss is the only known lifestyle intervention that can improve erectile dysfunction.[62]

Stress Urinary Incontinence

Pelvic floor weakness leading to stress urinary incontinence (SUI) in women is aggravated by increased intraabdominal pressure and is closely associated with truncal obesity. A report examined the association of bladder function with smoking, food consumption, and obesity in 6424 women with SUI and found a strong relationship between SUI and obesity.[63] These findings were confirmed in a questionnaire-based study conducted in Norway involving 27,936 women.[64] The proposed underlying mechanism for the association between high BMI and incontinence is that a high BMI leads to increased intravesical pressures and thus lowers the differential between the detrusor pressure and leak point pressure such that incontinence is more likely to occur.[65] With regard to the perioperative effect of obesity in surgical treatment of SUI, a study involving 250 women who underwent retropubic anti-incontinence procedures revealed that operative time was significantly longer for obese women; however, blood loss and major perioperative complications were similar across BMI groups.[66]

Urolithiasis

Urinary stone formation has been linked to obesity, as illustrated by a report on 527 calcium oxalate stone formers wherein an increased BMI was strongly associated with an elevated risk of stone formation for both men and women.[67] However, a retrospective study of 5492 stone formers revealed that the association between obesity and stone formation was significant only in women.[68] In a study conducted at Duke University, the major metabolic abnormalities found in obese stone formers that were possible contributors to recurrent stone formation were hypocitraturia, gouty diathesis, and hyperuricosuria.[69] An inverse association between pH and body weight suggests that production of excessively acidic urine promotes uric acid nephrolithiasis in obese stone formers.[70]

With respect to urologic procedures to treat stone disease, obesity adversely affects outcome following extracorporeal shock wave lithotripsy (ESWL). In a report examining clinical and radiologic variables associated with poor outcome after ESWL, along with obesity, pelvic ureteral stones, stones >10 mm, and obstruction were independent predictors of unsuccessful outcome.[71] Thus, because of the probability of treatment failure, obese patients, particularly those with a skin-to-stone distance of >10 cm, may be better served by endourologic procedures than by ESWL.[72,73]

Malnutrition

At the opposite end of the nutritional spectrum from overnutrition and obesity is malnutrition. With regard to the surgical patient, malnutrition has been associated with an increased incidence of nosocomial infection, poor wound healing, an increased length of hospital stay, multiorgan dysfunction, and mortality.[74] Various scientific investigations have demonstrated that deterioration of nutritional status has an invariably deleterious effect on surgical outcome. As early as 1932, Cuthbertson reported the association of impaired wound healing with negative nitrogen balance in trauma patients.[75] A more recent prospective study conducted in a cohort of patients who did not have cancer used four clinical parameters to predict perioperative morbidity:

1. Percentage of ideal body weight
2. Preoperative percentage of weight loss
3. Arm muscle circumference
4. Serum albumin.

Results of the study revealed that patients with at least one abnormal clinical parameter had a significant increase in the incidence of major complications and in length of hospital stay relative to patients with normal preoperative parameters.[76] Not only has malnutrition per se been implicated in surgical complications but also certain types of nutrient deficiency, protein malnutrition in particular, may lead to more severe postoperative problems. Relative to protein-calorie malnutrition, which is characterized by a lack of both proteins and carbohydrates, severe protein malnutrition leads to low serum albumin concentration,

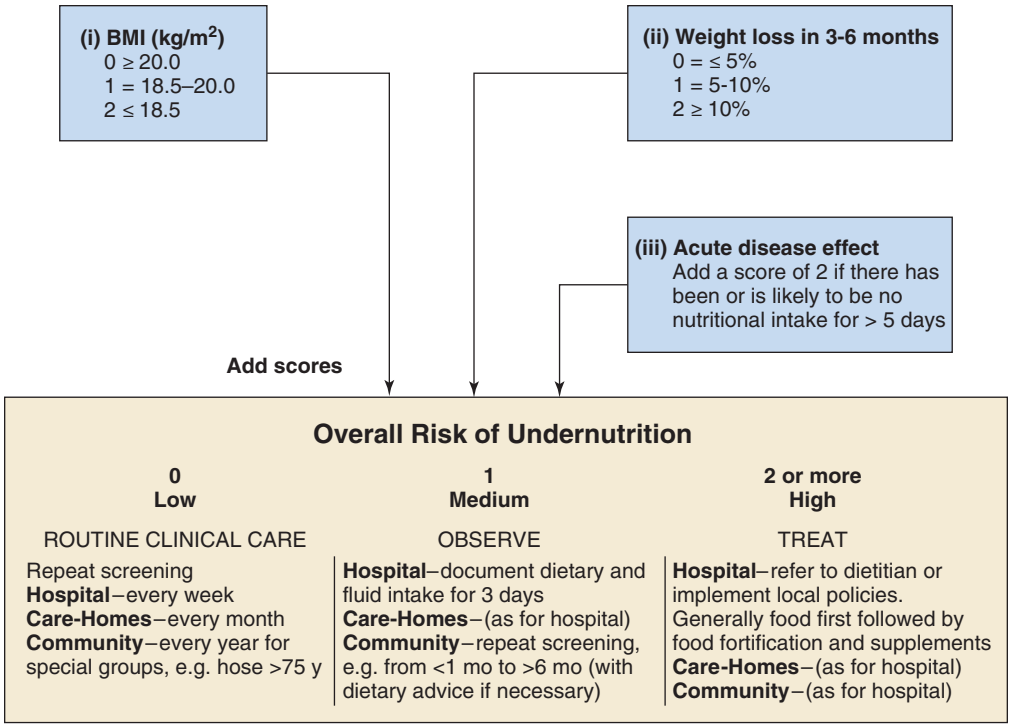


Figure 1.3 Malnutrition Universal Screening Tool. (With permission from Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. Clinical nutrition (Edinburgh, Scotland). 2003;22(4):415-21.)

edema, and a high prevalence of acute infections.[77] Thus, it is evident that nutritional status is a key clinical parameter demanding thorough evaluation in the surgical patient to prevent nutrition-related complications.

Nutritional Status Assessment

Traditionally, clinicians relied on anthropometric measurements, which they compared with tables providing ideal weight-for-height estimates to evaluate the nutritional status of patients.[78] Clinicians also determined body mass composition determinants such as lean body mass based on limb skinfold or circumference measurements and used these variables as indicators for adequacy of nutrition. However, problems pertaining to the precision of anthropometric measurements, wide intra-observer and inter-observer variations, and the lack of reliable reference standards have challenged the validity of these methods in ascertaining nutritional health of the surgical patient.[74] These issues surrounding the traditional methods of screening for malnutrition led to an interest in studying serum markers for more accurate determination of preoperative nutritional competence. However, the use of serum markers to diagnose malnutrition is fraught with inaccuracy, as the most commonly used serum markers, albumin and prealbumin, are affected by multiple conditions other than malnutrition, including inflammation, liver disease, and kidney disease.

In the absence of reliable serum markers to judge nutritional status and challenges applying anthropometric measurements, the next best option for nutritional assessment may be screening tools such as the Malnutrition Universal Screening Tool (MUST)[79] or the NRS 2002.[79,80] MUST was designed to be used in the community and factors in BMI, weight loss, and acute disease effect, with referral to a dietitian recommended for a score ≥2 (Fig. 1.3). The NRS 2002, validated for in-hospital use, provides an initial screening based upon a BMI <20.5, recent weight loss, reduced dietary intake, and the presence of severe illness (Tables 1.1 and 1.2). During an inpatient hospitalization, nutritional plans are advised for patients with NRS-2002 scores of ≥3.

An evolving tool for preoperative assessment with bearing upon nutritional status is sarcopenia, a condition characterized by progressive and generalized loss of skeletal muscle mass and strength.[81] Sarcopenia is commonly measured by assessing psoas muscle density and total psoas area on preoperative CT scan.[82] Sarcopenia has been correlated with major postoperative complications in women following radical cystectomy[83] and with infectious complications in both men and women undergoing radical cystectomy.[84] While interesting and objective, measurement of total psoas area and psoas muscle density has not yet transitioned from retrospective research to mainstream clinical practice.

Preoperative Management of Malnutrition

While preoperative nutritional support has been found to improve surgical outcomes in other specialties, limited data exist in the urologic literature. Pilot studies with immunonutrition among bladder cancer patients undergoing radical cystectomy reveal an association of immunonutrition with decreased postoperative complications, including infections and paralytic ileus.[85,86] Larger studies are anticipated.

Applying data from other surgical fields, preoperative nutritional support may be useful for patients with severe malnutrition. In a study of 1085 abdominal surgery patients, patients with a NRS 2002 assessment score of ≥5 who received preoperative enteral or parenteral nutrition had fewer postoperative complications and a shorter length of stay as compared to those patients with severe malnutrition who did not receive preoperative nutritional supplementation.[87] When possible, enteral feeding, rather than parenteral, should be provided, as enteral nutrition is associated with fewer infectious complications and better glycemic control.[88] Among patients with mild-to-moderate malnutrition, there is no proven benefit to preoperative nutritional supplementation.[87,89] In a systematic review and meta-analysis of preoperative nutrition among patients undergoing gastrointestinal surgery, no differences in overall complications, infectious complications, or length of stay were identified among patients receiving preoperative liquid oral supplements as compared to those receiving usual care or dietary advice.[90]

Table 1.1 Initial Screening

1	Is BMI <20.5?	Yes	No
2	Has the patient lost weight within the last 3 months?		
3	Has the patient had a reduced dietary intake in the last week?		
4	Is the patient severely ill? (e.g., in intensive therapy?)		

Yes: If the answer is 'Yes' to any question, the screening in Table 1.2 is performed.
No: If the answer is 'No' to all questions, the patient is re-screened at weekly intervals. If the patient, e.g., is scheduled for a major operation, a preventive nutritional care plan is considered to avoid the associated risk status.

(With permission from Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. Clinical nutrition (Edinburgh, Scotland). 2003;22(4):415-21.)

Infection and Urosepsis

Although community-acquired urinary tract infections (UTIs) are very common and are considered relatively easy to treat, complicated UTIs such as those acquired in the hospital setting are a legitimate cause for concern in urology. The term *complicated UTI* connotes infections brought about by a functional or anatomic abnormality in the urinary

Table 1.2 Final Screening

Impaired Nutritional Status		**Severity of Disease (≈ Increase in Requirements)**	
Absent Score 0	Normal nutritional status	Absent Score 0	Normal nutritional requirements
Mild Score 1	Wt loss >5% in 3 mths or food intake below 50–75% of normal requirement in preceding week	Mild Score 1	Hip fracture* Chronic patients, in particular with acute complications: cirrhosis*, COPD*. *Chronic hemodialysis, diabetes, oncology*
Moderate Score 2	Wt loss >5% in 2 mths or BMI 18.5–20.5 + impaired general condition or food intake 25–60% of normal requirement in preceding week	Moderate Score 2	Major abdominal surgery* Stroke* *Severe pnuemonia, hematologic malignancy*
Severe Score 3	Wt loss >5% in 1 mnth (>15% in 3 mths) or BMI <18.5 plus impaired general condition or food intake 0–25% of normal requirement in preceding week	Severe Score 3	Head injury* Bone marrow transplantation* *Intensive care patients (APACHE >10)*
Score	+	Score	= Total Score
Age	If ≥70 years: add 1 to total score above	= age-adjusted total score	

Score ≥3: the patient is nutritionally at risk, and a nutritional care plan is initiated.
Score <3: weekly screening of the patient. If the patient, e.g., is scheduled for a major operation, a preventive nutritional care plan is considered to avoid the associated risk status.

NES 2002 is based on an interpretation of available randomized clinical trials.
*indicates that a trial directly supports the categorization of patients with that diagnosis.
Diagnoses shown in *italics* are based on the prototypes given below.
Nutritional risk is defined by the present nutritional status and risk of impairment of present status, due to increased requirements caused by stream metabolism of the clinical condition.
A nutritional care plan is indicated in all patients who are (1) severely undernourished (score = 3), or (2) severely ill (score = 3), or (3) moderately undernourished + mildly ill (score 2+1), or (4) mildly undernourished + moderately ill (score 1 + 2).
Prototypes for severity of disease
Score = 1: a patient with chronic disease, admitted to hospital due to complications. The patient is weak but out of bed regularly. Protein requirement is increased but can be covered by oral diet or supplements in most cases.
Score = 2: a patient confined to bed due to illness, e.g., following major abdominal surgery. Protein requirement is substantially increased but can be covered, although artificial feeding is required in many cases.
Score = 3: a patient in intensive care with assisted ventilation, etc. Protein requirement is increased and cannot be covered even by artificial feeding. Protein breakdown and nitrogen loss can be significantly attenuated.
(With permission from Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. Clinical nutrition (Edinburgh, Scotland). 2003;22(4):415-21.)

tract, but it may also be used to indicate an infection that occurs in a patient with altered defense mechanisms.[91] When an infection previously localized to the urinary tract enters the bloodstream and causes a systemic infection, urosepsis ensues.

Judicious use of prophylactic antibiotics in surgical procedures has served to minimize the incidence of these preventable yet potentially lethal complications in urologic practice.[92] However, the rising incidence of antimicrobial resistance, especially of gram-positive pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE), can lead to treatment failure and life-threatening sepsis.[93] Moreover, the increasing numbers of patients who are immunocompromised either by an underlying disease (e.g., HIV/AIDS) or through concurrent medical therapy (e.g., steroids, chemotherapy)[94] also lead to greater infection risk. These risk factors are particularly relevant when surgery entails instrumentation and manipulation of the urinary tract. Given that certain host factors predispose the urologic patient to complicated infection, it is necessary to determine the need for antimicrobial prophylaxis preoperatively and to prevent the occurrence of systemic septicemia.

Both demographic factors and medical conditions play a role in susceptibility to complicated UTI. Advanced age in a patient should alert the urologist to the possible presence of UTI. The prevalence of UTI increases with age and reaches approximately 3.6% in men ≥70 years old and 7% in women ≥50 years old.[95] As previously discussed, nutritional imbalances leading to obesity and malnutrition could impair cellular immunity and thereby predispose patients to UTI. Preexisting local or systemic infections intuitively are associated with complicated UTI.

Recent antimicrobial use has been linked to complicated UTI, possibly through two mechanisms: (1) antibiotic therapy fails, and the initial infection, either systemic or local, progresses to complicated UTI or frank urosepsis; or (2) antibiotics used to eliminate competing pathogens promote the growth of resistant strains and lead to infection with a more virulent strain.[96] Diabetes mellitus not only increases the incidence of UTI in adults but also contributes to a complicated course despite antibiotic prophylaxis and treatment. This situation is the result of defects in the secretion of urinary cytokines and increased adherence of microorganisms to the uroepithelial cells in diabetic patients.[97]

Not surprisingly, many urologic and medical renal conditions are associated with an increased incidence of complicated UTIs and urosepsis. One of the most consistent contributors to complicated UTI is obstruction of the urinary tract.[98] This underlying mechanism encompasses the following: intrinsic disorders of the kidney, renal pelvis, and ureters (e.g., congenital anomalies including vesicoureteral reflux, renal or ureteral calculi, neoplasms, strictures); extrinsic abnormalities of the upper urinary tract (e.g., aberrant vessels, retroperitoneal hematomas or fibrosis, nonurologic neoplasms); and disorders of the bladder and bladder neck (e.g., BPH, prostate and bladder cancer, cystolithiasis, bladder neck contracture) and urethra (e.g., valves, strictures). Functional impairment of the bladder, as seen in spastic or atonic neurogenic bladders, may have the same consequences as conditions causing physical obstruction.[99] Renal diseases, whether unilateral, bilateral, or segmental, may also complicate UTI and include conditions such as azotemia, polycystic kidney disease, and papillary necrosis, as well as nephropathies brought about by abuse of analgesics such as nonsteroidal antiinflammatory drugs.[100]

Immunosuppressed urologic patients present a unique problem with regard to susceptibility to complicated UTI. Whether impairment of immunologic response was brought about iatrogenically (e.g., patients with cancer who are undergoing chemotherapy, transplant recipients receiving steroids) or was the result of a disease process (e.g., HIV/AIDS, persistent neutropenia or granulocytopenia),[94] avid use of broad-spectrum antibiotics not only for common infections but also for opportunistic organisms should be considered by the urologist for an optimal clinical outcome. Finally, urologic instrumentation leads to an increased probability of introducing microorganisms into an otherwise sterile urinary tract and thus predisposes patients to infections. The same principle applies to urologic procedures in which foreign bodies are purposefully left in the human body (e.g., ureteral stents, penile prostheses).[101] Although intended to elicit only a minimal inflammatory response, any foreign body can serve as a nidus of infection and must be removed promptly when it is determined to be the source of infection or when its presence in the body contributes to a complicated UTI.

Quantifying Comorbidity

In medicine, *comorbidity* is defined as the effect of all other pathologic conditions an individual patient may have other than the primary disease of interest. The very nature of comorbidities, as secondary or lesser diseases of interest, has led to some indifference among practicing clinicians and research investigators regarding the significance of these illnesses in treatment decision making and survival outcomes. Because of the significant correlation between advanced age and increased prevalence of preexisting comorbidities at the time of surgery, physicians have traditionally used age as a surrogate for the effects of concurrent medical conditions, especially in elderly urologic patients.[102] Although no one can discount the value of age in treatment decisions, the use of age as a strict criterion that may deny appropriate curative therapy to healthy older patients is unacceptable and may even have litigious consequences.

The impact of comorbidities is substantial in the field of urology, particularly in urologic oncology. An analysis of 34,294 newly diagnosed cases of cancer in patients from the Netherlands Eindhoven cancer registry showed that, aside from lung cancer (58%) and stomach cancer (53%), the crude prevalence of comorbidities was highest in malignant diseases of the kidney (54%), bladder (53%), and prostate (51%).[103] In terms of prognosis, Post and colleagues[104] acknowledged that comorbidity was the most important prognostic factor for 3-year survival in a population-based study of 1337 patients with localized prostate cancer. In a series of 1023 consecutive radical nephrectomies and nephron-sparing surgical procedures for RCC in Dresden, Germany, comorbidities were closely associated with overall morbidity and mortality.[105] With regard to treatment-related side effects, both peripheral vascular disease and

diabetes have been shown to be significant risk factors for development of impotence following external beam radiation for prostate cancer as well as for gastrointestinal and genitourinary toxicities.[106] Thus, comorbidities can affect almost all aspects of urologic disease but most importantly the incidence of posttreatment morbidity and all-cause death.

Up until the late 1980s, the effects of comorbidities were largely unquantifiable and subjective. As a result, certain beliefs and attitudes in clinical practice were based mostly on anecdotal data rather than on appropriate evidence-based information. The need for methods to quantify the effects of comorbidities led to the development of comorbidity scoring systems, which are gaining utility for both research and clinical purposes.

The most extensively studied and most commonly used comorbidity scoring scheme in medicine is the *Charlson Index score*.[107] Dr. Mary E. Charlson, a clinical epidemiologist and methodologist who was interested in improving clinical outcome in both medical and surgical patients, first published the index in 1987 at Cornell University in Ithaca, New York. The Charlson Index is a list of 19 pathologic conditions (Table 1.3). Based on the proportional hazards regression model that Charlson constructed from clinical data, each condition is assigned a weight from 1 to 6. The Charlson Index score is the sum of the weights for all concurrent diseases aside from the primary disease of interest. Thus, for example, in men with prostate cancer, although cancer is generally assigned a score of 2, in this case, men are assigned no points for prostate cancer because it is the primary index disease. In a cohort of 685 patients with breast cancer in the original study, the Charlson Index score showed a strong association of a 2.3-fold increase in the 10-year risk of mortality per 1-point increment in the comorbidity level.

Table 1.3 Weighted Index of Comorbidity [Defined by the Charlson Index]

Assigned Weights for Diseases	Conditions
1	Myocardial infarct Congestive heart failure Peripheral vascular disease Cerebrovascular disease Dementia Chronic pulmonary disease Connective tissue disease Ulcer disease Mild liver disease Diabetes
2	Hemiplegia Moderate or severe renal disease Diabetes with end organ damage Any tumor Leukemia Lymphoma
3	Moderate or severe liver disease
6	Metastatic solid tumor AIDS

Assigned weights for each condition that a patient has. The total equals the score. Example: chronic pulmonary (1) and lymphoma (2) = total score (3).

(With permission from Charlson ME, Pompei P, Ales K, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987;40:373-83.)

The Charlson Index score provides a simple means to quantify the effect of comorbid illnesses, incorporate the severity of a particular disease (diabetes without complications versus diabetes with end-organ damage), and account for the aggregate effect of multiple concurrent disease processes on clinical outcome, most often mortality. In prostate cancer research, the Charlson Index score has been extensively evaluated as a predictor of both cause-specific mortality and all-cause mortality. Albertsen and colleagues[108] showed that the Charlson Index score provided significant predictive information on cancer-specific and all-cause survival independent of age, Gleason score, or clinical stage in a cohort of 451 patients with Jewett-Whitmore stage A1-B prostate cancer treated with hormonal ablation. In 2002, a competing risk analysis of 751 men who underwent radical prostatectomy for clinically localized prostate cancer at the Mayo Clinic in Rochester, Minnesota, showed that, whereas the Gleason score emerged as the only significant predictor of prostate cancer–specific mortality, both the Charlson Index score and the Gleason score were predictive of overall mortality.[109] Comparable results were reported by other groups who performed similar analyses using Charlson Index scores in prostate cancer outcome studies.[104,110,111] With recent efforts to minimize the overtreatment of men with prostate cancer, the Charlson Index has a critical predictive role. In a retrospective study of 1482 men with nonmetastatic prostate cancer diagnosed from 1997 to 2004, each point increase in Charlson score was associated with a twofold increase in hazard of nonprostate mortality. After stratification by tumor risk, prostate cancer mortality was rare among low-risk and intermediate-risk groups, leading to the recommendation that men with the highest Charlson scores should consider conservative management of low-risk and intermediate-risk tumors.[112,113] In a larger study of 140,553 men aged ≥ 66 years with early-stage prostate cancer who were diagnosed between 1991 and 2007 from the Surveillance, Epidemiology, and End Results-Medicare database, men with Charlson scores ≥ 3 were found to garner no survival benefit from aggressive treatment.[114]

The clinical utility of the Charlson Index score extends to other urologic diseases as well. With regard to bladder cancer, the Charlson Index score was evaluated in predicting adverse pathologic characteristics, cancer-specific death, and overall survival following radical cystectomy.[115] Logistic regression revealed that the Charlson Index score was independently associated with an increased risk of extravesical disease. Cox regression models further revealed that the index was significantly associated with decreased cancer-specific survival. In 302 men undergoing transurethral resection of the prostate (TURP) or simple prostatectomy for BPH, the Charlson Index score correlated with 5-year mortality.[116] Thus, even for nononcologic urologic operations, comorbidity indices have demonstrated power for predicting mortality following surgery.

Other indices of comorbidity are available but have not been as broadly used as the Charlson Index. Three prime examples are the Index of Co-Existent Disease (ICED),[117] the Kaplan-Feinstein Index (KFI),[118] and the Cumulative Illness Rating Scale (CIRS).[119] Similar to the Charlson Index, the

ICED, KFI, and CIRS are designed to measure the impact of concurrent diseases on prognosis. Because of the lack of definitive head-to-head comparisons of the various comorbidity assessments, no clear-cut evidence exists to establish the advantage of one scale over the other.[120] In fact, in a study in which Charlson Index scores were shown to be predictive of 5-year mortality following TURP for BPH, similar analysis using the KFI and ICED demonstrated comparable predictive power.[116]

Conclusion

It is the ultimate goal of every urologist to provide the best possible care for the urologic patient. The projected surge in life expectancy in the new millennium translates into an analogous increase in urologic patients who will potentially present with various comorbid diseases. These patients will require thorough evaluation including the addressing of associated comorbidities to obtain an excellent outcome. The impact of host factors and comorbidities cannot be taken lightly because more and more scientific evidence points to associations of these pretreatment parameters with a heightened risk for undesirable posttreatment complications. In particular, obesity, which is associated with other significant comorbidities and has been found to affect both the urologic disease process and consequent complications, must be investigated comprehensively. Furthermore, adequate assessment of nutritional status to ensure sufficient nutritional support in the surgical patient is also warranted.

Patients with host factors that predispose them to infections may require prophylactic antibiotic coverage and must be closely monitored to anticipate the need for further antimicrobial treatment to prevent urosepsis. Finally, various comorbidity scoring systems are being investigated for their clinical value and may further provide urologists and other clinicians with more accurate predictive models for assessing the risk of complications among patients with urologic diseases. As subsequent chapters in this book delve into more organ-specific, urologic disease–specific, or procedure-specific complications, we encourage the readers to make every effort in taking a broad, encompassing approach when evaluating urologic patients by diligently considering the effects of comorbid conditions in each individual person.

References

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Chapter 1 Questions

1. By 2050, the estimated population of the United States ≥65 years of age will be:
   a. 25 million
   b. 42 million
   c. 67 million
   d. 88 million
   e. 110 million

2. Obesity is associated with increased rates of:
   a. Erectile dysfunction
   b. Stress urinary incontinence
   c. Kidney cancer
   d. Uric acid nephrolithiasis
   e. All of the above

3. What is the calculated BMI of a patient who is 6'0" tall and weighs 221 pounds?
   a. 24.3
   b. 27.8
   c. 30.2
   d. 33.2
   e. 38.6

4. Compared to men of normal weight, obese men have:
   a. Lower PSA levels
   b. Lower PCA3 levels
   c. Lower % free PSA levels
   d. Higher PSA levels
   e. Higher PCA3 levels

5. A validated tool that may be used for the assessment of inpatient nutritional status is:
   a. NRS 2002
   b. MUST
   c. MMSE
   d. Albumin
   e. Prealbumin

6. A 79-year-old male with muscle invasive bladder cancer is scheduled to undergo a radical cystectomy. He has a history of chronic obstructive pulmonary disease, congestive heart failure, obesity, and obstructive sleep apnea. What is his Charlson comorbidity score?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

7. Which of the following statements regarding prostate cancer and obesity is *incorrect*?
   a. Obese men with prostate cancer have lower serum prostate-specific antigen levels relative to men of normal weight
   b. Among men undergoing an open retropubic prostatectomy, increasing BMI is associated with increasing operative time and increasing intraoperative blood loss
   c. Mildly obese men undergoing radical prostatectomy have worse health-related quality of life postoperatively than men of normal weight
   d. Men with higher BMIs present with higher-grade tumors and more advance pathologic stages
   e. Increased body weight was found to be associated with an increased risk of death from prostate cancer in a large, prospectively studied population[31]

8. A 67-year-old male just underwent emergent stent placement for a 7 mm proximal right ureteral calculus with associated hydronephrosis, a fever of 101.7°F (38.7°C), and a blood pressure of 86/57. Risk factors in his history that increase his risk for urosepsis include:
   a. Ongoing cisplatin and etoposide chemotherapy for treatment of small cell lung cancer
   b. An indwelling Foley catheter for a recent episode of acute urinary retention
   c. Prednisone taper following a recent diagnosis of herpes zoster ophthalmicus
   d. Obstructing urolithiasis
   e. All of the above

9. In urologic diseases, comorbidity indices have demonstrated power for predicting mortality among patients undergoing:
   a. RPLD for testis cancer
   b. InterStim placement for refractory urinary urgency/frequency
   c. Transobturator sling placement for stress urinary incontinence
   d. Transurethral resection of the prostate for BPH
   e. Percutaneous nephrolithotomy for nephrolithiasis

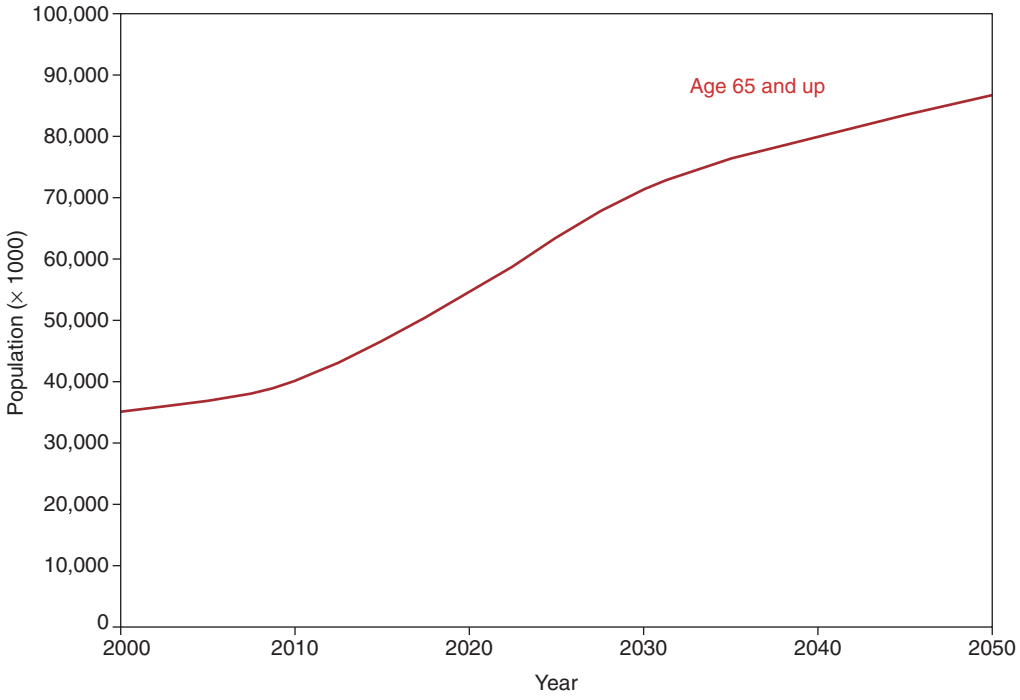
10. The most important prognostic factor for 3-year survival among men with localized prostate cancer is:
    a. Gleason score
    b. PSA doubling time
    c. Comorbidities
    d. Clinical stage
    e. Interval of time between initial treatment and biochemical recurrence

Answers

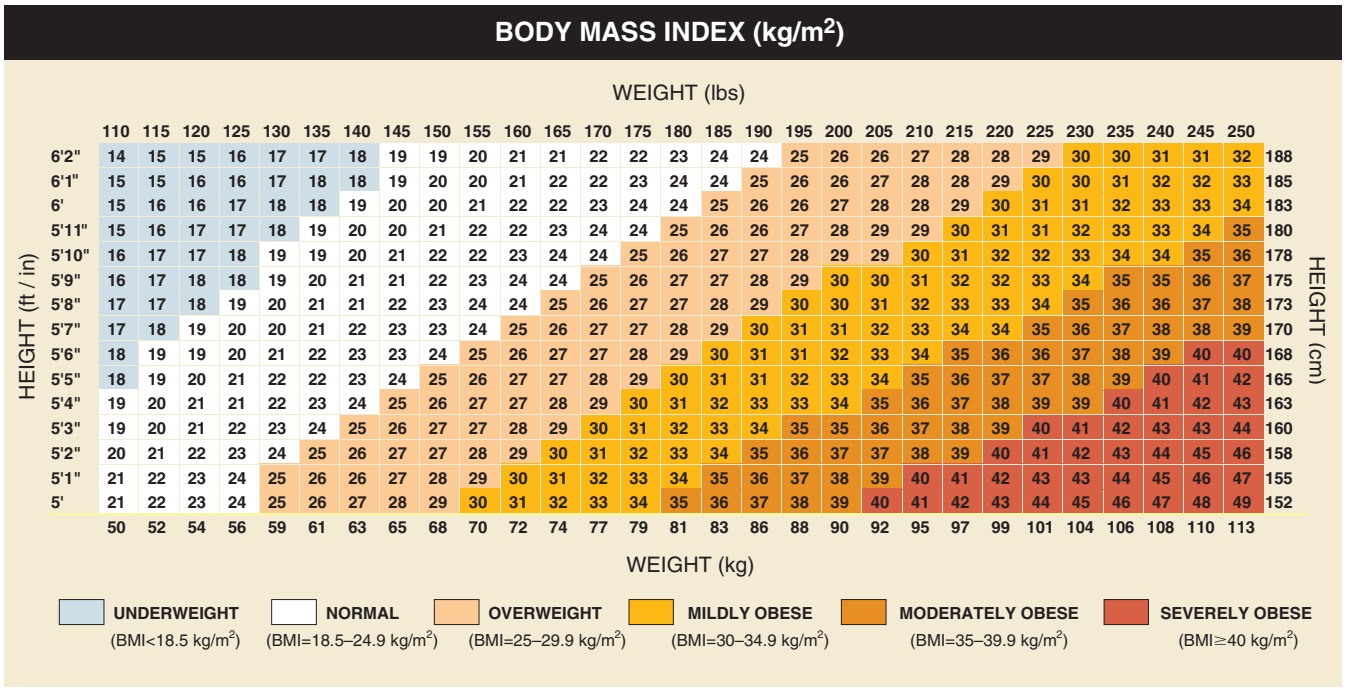
1. **d.** According to the US Census Bureau, and as illustrated in Case Fig. 1.1, the US population ≥65 years of age is exponentially growing and is estimated to reach approximately 88.5 million by 2050.
2. **e.** In Dr. Mydlo's article "The impact of obesity in urology," he reviewed that obesity is a risk factor for stress urinary incontinence, erectile dysfunction, infertility, renal cell carcinoma, and renal calculi.
3. **c.** Using the formula BMI = Weight (in kilograms)/height (in meters) squared, 100 kg/(1.82 m)^2 = 30.2. Alternatively, using Case Fig. 1.2, a man who is 6'0" tall and weighs 220 pounds has a BMI of 30, falling within the mildly obese group.
4. **a.** In Baillargeon's population-based study of 2779 men without prostate cancer, mean PSA decreased in

a linear fashion with an increase in BMI category, from 1.01 ng/mL in normal-weight men to 0.69 ng/mL in obese men, after adjusting for race/ethnicity and age.

5. **a.** The NRS 2002 is a predictive, validated assessment tool for screening of undernutrition in hospitalized patients. In contrast, the Malnutrition Universal Screening Tool (MUST) is used to detect undernutrition among community-dwelling adults. While widely used as assessments for nutritional status, albumin and prealbumin are affected by many disease processes, including liver disease, kidney disease, and acute inflammation and are therefore unreliable for monitoring nutritional status.
6. **b.** The patient receives 1 point each for his diagnoses of chronic obstructive pulmonary disease and congestive heart failure. As his bladder cancer is our primary disease of interest, the patient receives no points for that diagnosis.
7. **c.** Thus far, prospective studies have failed to demonstrate large differences in postoperative health-related quality of life between mildly obese men and men of normal weight.
8. **e.** One of the most consistent contributors to complicated urinary tract infections is obstruction of the urinary tract, including obstruction due to ureteral calculi. Indwelling catheters are associated with an increased risk of urosepsis. Patients on chemotherapy or immunosuppression due to steroids are also at increased risk for urosepsis.
9. **d.** In Krousel-Wood et al.'s study of 302 men undergoing transurethral resection of the prostate (TURP) or simple prostatectomy for BPH, the Charlson Index score correlated with 5-year mortality.
10. **c.** Post and colleagues found that comorbidity was the most important prognostic factor for 3-year survival in a population-based study of 1337 patients with localized prostate cancer.



Case Figure 1.1



HEIGHT (ft / in)	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250	HEIGHT (cm)
6'2"	14	15	15	16	17	17	18	19	19	20	21	21	22	22	23	24	24	25	26	26	27	28	28	29	30	30	31	31	32	188
6'1"	15	15	16	16	17	18	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	28	29	30	30	31	32	32	33	185
6'	15	16	16	17	18	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	28	29	30	31	31	32	33	33	34	183
5'11"	15	16	17	17	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	29	29	30	31	31	32	33	33	34	35	180
5'10"	16	17	17	18	19	19	20	21	22	22	23	24	24	25	26	27	27	28	29	29	30	31	32	32	33	34	34	35	36	178
5'9"	16	17	18	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	30	31	32	32	33	34	35	35	36	37	175
5'8"	17	17	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	30	31	32	33	33	34	35	36	36	37	38	173
5'7"	17	18	19	20	20	21	22	23	23	24	25	26	27	27	28	29	30	31	31	32	33	34	34	35	36	37	38	38	39	170
5'6"	18	19	19	20	21	22	23	23	24	25	26	27	27	28	29	30	31	31	32	33	34	35	36	36	37	38	39	40	40	168
5'5"	18	19	20	21	22	22	23	24	25	26	27	27	28	29	30	31	31	32	33	34	35	36	37	37	38	39	40	41	42	165
5'4"	19	20	21	21	22	23	24	25	26	27	27	28	29	30	31	32	33	33	34	35	36	37	38	39	39	40	41	42	43	163
5'3"	19	20	21	22	23	24	25	26	27	27	28	29	30	31	32	33	34	35	35	36	37	38	39	40	41	42	43	43	44	160
5'2"	20	21	22	23	24	25	26	27	27	28	29	30	31	32	33	34	35	36	37	37	38	39	40	41	42	43	44	45	46	158
5'1"	21	22	23	24	25	26	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	43	44	45	46	47	155
5'	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	152
	50	52	54	56	59	61	63	65	68	70	72	74	77	79	81	83	86	88	90	92	95	97	99	101	104	106	108	110	113	

Case Figure 1.2

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2 Preoperative Pulmonary Assessment and Management of Pulmonary Complications

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CHAPTER OUTLINE

Preoperative Pulmonary Assessment
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KEY POINTS

1. Accurate preoperative identification of patients at risk for developing postoperative pulmonary complications optimizes preoperative testing and ideally minimizes occurrence of postoperative complications.
2. Risk factors for respiratory complications stem from patient-related factors as well as from procedure-related factors including surgical site, duration of surgery, and type of anesthesia. Procedure-related factors carry the highest risk for postoperative pulmonary complications.
3. Urologists should identify and inform patients who smoke of the associated risk factors for pulmonary complications as well as for urothelial cancer. Cigarette smoking cessation should be 4 weeks or more prior to surgery to begin to provide benefit.
4. Multiple new preoperative risk calculators are available to assist in assessing risk stratification. The most important patient-related risk factor is age, increasing significantly over the age of 50.
5. Recommendations for patients undergoing major urologic procedures include intermittent pneumatic compression, use of graduated compression stockings, early and frequent ambulation, in addition to pharmacologic venous thromboembolism (VTE) prophylaxis when possible.

Multiple studies evaluating complications following noncardiac surgery demonstrate that postoperative pulmonary complications (PPCs) occur at similar frequency and result in similar rates of morbidity and mortality as cardiovascular complications.[1,2] The reported rates of PPCs range from 5% to 40%, dependent upon procedure risk, with PPC-associated mortality risks ranging from 10% to 25%.[3–7] Data from the National Surgical Quality Improvement Program (NSQIP) demonstrate that PPCs are the most costly of postoperative complications and result in the longest hospital length of stay.[8]

Although there is no exact definition of what constitutes a PPC, most literature includes conditions such as atelectasis, infection (pneumonia, bronchitis), respiratory failure

requiring prolonged mechanic respiratory support, acute respiratory distress syndrome (ARDS), and hypoxemia.[7,9] For the purposes of this chapter, we have also included discussion regarding pulmonary embolism and additional surgical complications such as pneumothorax. The economic impact of PPCs has been estimated to account for 3.4 billion dollars in health care costs in the United States.[10] Ultimately, prevention of PPC requires careful assessment of risk factors, both from patient characteristics and procedure-associated factors. Proper identification of these risk factors aids development of strategies to prevent these complications.

Preoperative Pulmonary Assessment

Identifying the primary risk factors associated with PPCs assists with accurate risk stratification prior to surgery and informs strategies to reduce morbidity and mortality. Pulmonary risks factors stem from two sources, preexisting patient characteristics as well as procedure-associated factors.

PATIENT FACTORS

Identifying factors that predispose to the development of PPC requires an understanding of the principal patient-related risk factors as well as an understanding of the degree of risk associated with these factors. The American College of Physicians (ACP) provides guidelines for assessing PPC risk factors for noncardiopulmonary surgery. These guidelines stem from a systematic review of the existing literature performed by Smetana and colleagues.[1,2] This work, published in 2006, remains the largest evidence-based source of information regarding PPC. From these data, the primary patient-related factors associated with increased risk of PPCs and are detailed in Table 2.1.

The most important patient-related risk factors found by this review are patient age and presence of an increased American Society of Anesthesiologist's (ASA) score.[1,11] Age confers an increasing level of risk for PPC for each decade over 50. Ultimately, as age increases beyond 80, the odds ratio increases to 5.63 as compared to patients younger than 50. Given that the population requiring major urologic surgery is often in this age range, this risk factor becomes especially pertinent to consider during urologic preoperative evaluation.[12,13]

The existence of chronic lung diseases such as chronic obstructive pulmonary disease (COPD) warrants special consideration when assessing PPC risk. In fact, the presence of chronic lung disease represents the most common risk factor identified by Smetana and colleagues. However, the degree of this risk factor varies widely upon the degree of pulmonary impairment. Consequently, the presence of preoperative congestive heart failure (CHF) confers a higher risk for PPC than COPD (OR 2.93 vs 2.36, respectively).

Additional significant risk factors for PPC include active cigarette use and decreased overall functional dependence. More recently, data regarding obstructive sleep apnea (OSA) indicate that OSA confers an increased risk for immediate airway management complications as well as for PPC.[14–16]

Table 2.1 Primary Patient Related Risk Factors From the American College of Physicians Guideline

Risk Factor	Odds Ratio for PPC	95% Confidence Interval
Age		
50–59	1.50	1.31–1.71
60–69	2.09	1.65–2.64
70–79	3.04	2.11–4.39
≥80	5.63	4.63–6.85
ASA Score ≥2	4.87	3.34–7.10
Congestive heart failure	2.93	1.02–8.03
Total functional dependence	2.51	1.99–3.15
COPD	2.36	1.90–2.93
Cigarette use	1.40	1.17–1.69

COPD, chronic obstructive pulmonary disease; PPC, postoperative pulmonary complication

(Adapted from Smetana GW, Lawrence VA, Cornell JE, American College of Physicians. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med. 2006;144(8):581-95.)

Patients should thus be screened for signs and symptoms of OSA prior to undergoing anesthesia. Several tools for assessing for OSA have been published and assist with assessing level of OSA risk.[17,18]

Interestingly, this systematic review did not find strong evidence demonstrating an increased risk of pulmonary complications amongst patients with obesity and controlled asthma, findings corroborated by additional studies.[3,19] However, obesity remains a risk factor for development of venous thromboembolic complications including pulmonary embolism and thus remains an important patient factor clinicians should consider when assessing risk.

While the ACP guideline provides a necessary evidence-based framework for assessing risk for PPC, the data have not been systematically updated for nearly 10 years. More recent data indicate that additional risk factors include respiratory infections within 1 month prior to surgery, diabetes, preoperative hypoxemia, and preoperative anemia.[3,4,20–22] Currently, prospective studies are under way to improve PPC definition and identify more accurate risk factors.[23]

Given that most patients requiring urologic intervention are over the age of 50, and many patients undergoing procedures associated with urothelial carcinoma have a history of significant tobacco use, the risk of PPC in this patient cohort warrants special attention. Prior exposure to bleomycin presents an additional urologic-specific patient risk factor that will be discussed in more detail later in the chapter.

CIGARETTE SMOKING

When considering patient-related factors, cigarette smoking warrants additional commentary. Smoking tobacco is a well-known risk factor for cardiac, vascular, infectious, and respiratory complications.[24–27] Many PPCs occur at a higher rate in smokers, conferring an increased risk with an odds

ratio of 1.4 to 4.3.[6,28] Tobacco smoking confers additional risk for urologic malignancies, increasing the risk of renal cell carcinoma and urothelial carcinoma, and continued tobacco use is associated with disease progression and recurrence.[29–34]

In their prospective study of 200 patients undergoing coronary artery bypass surgery, Warner and associates demonstrated that patients who had stopped smoking ≥8 weeks preoperatively had a significantly lower risk of pulmonary complications than did patients who were active smokers (14.5% vs 33%).[35] Moreover, patients who had stopped smoking for >6 months had pulmonary complication rates similar to those patients who had never smoked (11.1% vs 11.9%). Surprisingly, patients who had quit smoking <8 weeks preoperatively experienced more untoward pulmonary events than did active smokers (57% vs 33%). This appears to be due to increased airway reactivity and sputum production that occur in the initial period after smoking cessation.[9] Recent studies have corroborated these findings, indicating that smoking cessation ultimately benefits patients but requires 4 to 6 weeks to provide benefit.[36–38]

Given the important role cigarette smoking plays both in the pathophysiology of urologic malignancies and on the risk of PPC as well as other major postoperative complications, the urologist is in a unique position to intervene and provide guidance on smoking cessation. In addition, observational studies indicate that patients may be more receptive to quitting during the perioperative period.[39,40] A recent prospective study within a urology clinic demonstrated the efficacy of this approach.[41]

Patients who smoke should be identified preoperatively. The duration and amount of smoking should be quantified. These patients should be informed that smoking increases the perioperative risk and also that quitting can decrease this risk. Preoperative abstinence should be recommended for a minimum period of 4–6 weeks prior to surgery.

PROCEDURE FACTORS

Procedure-related factors associated with risks for PPC are displayed in Table 2.2 and are adapted from the ACP guideline.[1,2] In terms of risk assessment, procedure relegated factors represent the most significant predictors for development of PPC.

Table 2.2 Primary Procedure Related Risk Factors (American College of Physicians Guideline)

Risk Factor	Odds Ratio for PPC	95% Confidence Interval
Surgical site		
Aortic	6.90	2.74–17.3
Thoracic	4.24	2.89–6.23
Any abdominal	3.01	2.43–3.72
Upper abdominal	2.91	2.35–3.60
Emergency surgery	2.21	1.57–3.11
Surgery >3 hours	2.26	1.47–3.47

PPC, postoperative pulmonary complication
(Adapted from Smetana GW, Lawrence VA, Cornell JE, American College of Physicians. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med. 2006;144(8):581-95.)

Surgical Approach and Anatomic Considerations

Special consideration should be paid toward surgical anatomic location. While certain surgical sites (aortic, thoracic, neurologic) are not common in urologic procedures, it is important to note that abdominal surgical location confers an odds ratio of 3.01 and thus is a critical factor to be considered as risk factor for PPC. Regardless of proximity to the diaphragm, surgical trauma to the abdomen impacts respiratory function. Abdominal incisions decrease lung volumes in a restrictive pattern, resulting in reduction in vital capacity of 50–60% and functional residual capacity by approximately 30%.[42,43] Incisional pain limits respiratory motion, often subconsciously, promoting development of atelectasis and pleural effusions. Manipulation of the intestines during transperitoneal dissection can result in phrenic nerve stimulation, which further impairs normal respiratory function.[9,44]

Urologic procedures that involve, or are in close proximity to, the diaphragm represent a high-risk group. This category includes surgical approaches utilizing flank, subcostal, and thoraco-abdominal incisions. Additionally, minimally invasive renal surgery, upper retroperitoneal dissection, and percutaneous renal access present anatomic risk to the pulmonary space. Proximity to the diaphragm and pleural cavity may result in both obvious and discrete injury to the diaphragm and entry into pleural space. While these injuries are often recognized and managed intraoperatively, opportunity for occult injury should still be considered and postoperative assessment should address this risk.

Additional procedure-related factors include prolonged surgical time (>3 hours) and emergent procedures.[1,2]

Anesthesia

Evidence also supports that general anesthesia represents an independent risk factor for PPC. Induction of general anesthesia results in an immediate development of atelectasis due to collapse of lung tissue, ventilation-perfusion mismatch, creation of respiratory dead-space, hypoxemia, and decreased surfactant function.[9] Narcotics, sedatives, and other centrally acting drugs may depress respiratory drive and further increase risk for PPC.

PREOPERATIVE PATIENT EVALUATION

The evaluation of preoperative pulmonary risk begins with a detailed history and physical examination. Patients with a smoking history should be identified and efforts included to quantify duration and amount of smoking. A history of chronic lung disease should also be identified. A recent history of an upper respiratory infection, including influenza, should also be identified. A thorough pulmonary evaluation such as exercise intolerance, chronic cough, sputum production, previous pulmonary surgery, previous chemotherapy (see later), dyspnea at rest or on exertion, wheezing, rales, cyanosis, or weakness or debilitation assist in identifying patients at risk. Evaluation for signs of sleep apnea may also help with risk stratification.[17]

A chest radiograph should be obtained in all patients with any of the above risk factors or over the age of 50. However, clear evidence supporting a benefit from obtaining routine chest radiographs does not currently exist.

Evidence indicates that preoperative pulmonary function testing (PFT) does not accurately predict PPC, and consequently these tests are overused.[45,46] Debate continues regarding the value of PFT. The ACP systematic review concluded that PFT is reasonable for patients with COPD or asthma in whom clinical evaluation is unclear and in patients with unexplained dyspnea or exercise intolerance.[2,47]

As preoperative hypoalbuminemia predicts PPC, recognition of patients with severe malnourishment should be identified, and it is reasonable to recommend preoperative nutritional supplementation.[48,49]

Several risk calculators have been developed to provide quantitative assessment for pulmonary risk and are available online.[50–53] One example is the ARISCAT risk score, which was developed and validated from European surgical databases and uses five risk factors to predict risk of PPC.[3,54] This is shown in Table 2.1. Implementation of these risk calculators offers numerical risk evaluations that may assist with clinical decision making.

Preoperative Strategies

Once a patient is identified as having a higher risk for PPC, several strategies may be employed to decrease that risk. As stated above, urologists should instruct and guide current smokers to stop smoking and provide tools and referrals for patients that are willing to attempt cessation.

Patients with chronic lung disease who do not appear to be in optimal status should have surgery deferred until their pulmonary status has been medically optimized. Patients with a history of asthma should also be assessed for how well their asthma is controlled. At the time of surgery these patients should be free of wheezing and should use beta-agonist inhalers prior to intubation and during the perioperative period. Any signs of a recent upper respiratory infection, even for patients without a history of lung impairment, should prompt further workup and delay in surgical timing until recovery from respiratory infection is complete.

Preoperative pulmonary physical therapy has been shown to reduce postoperative atelectasis and hospital stay in patients undergoing cardiac surgery.[55–57] Preoperative teaching with incentive spirometry for all patients undergoing elective abdominal surgery results in improved understanding of the techniques and perioperative use.[58] It is our practice to provide this teaching and to reinforce incentive spirometry in the perioperative period.

Postoperative Strategies

The strategy for postoperative pulmonary rehabilitation differs from preoperative approaches in that postoperative tactics apply to every patient, regardless of preoperative risk level. These strategies focus on maneuvers aimed to counteract the surgical and anesthesia impairments on respiratory function. Adequate pain control and lung expansion through incentive spirometry (IS), coughing, and early ambulation comprise the cornerstone of such strategies.

INCENTIVE SPIROMETRY AND DEEP BREATHING EXERCISES

While a few small trials demonstrate that utilizing postoperative IS and deep breathing exercises (DBE) reduces PPC and length of stay,[58–60] a recent Cochrane review found no evidence that IS prevented PPC.[61] The authors concluded that the evidence for this conclusion is of low quality and that higher quality trials are needed to evaluate the efficacy of IS.

It remains our practice to employ incentive spirometry in both the immediate postoperative and perioperative period.

EARLY MOBILIZATION

Facilitating early ambulation improves fluid mobilization and increases respiratory utilization. While very few studies provide guidance on the impact of mobilization, one study demonstrated an increase in PPC for each additional day of delay in mobilization following abdominal surgery.[62] It remains our practice to encourage ambulation and routinely employ the assistance of physical therapists for patients that require assistance.

PAIN CONTROL

Adequate pain control ameliorates the pulmonary functional depression induced by surgical incisions and assists with early ambulation. However, use of opioid efficacy is limited by subsequent depression of the respiratory drive. Epidural anesthesia has been associated with fewer PPCs, including in patients with COPD undergoing abdominal surgery.[63,64] Intercostal nerve blockade may also help reduce PPC in patients undergoing subcostal or upper abdominal incisions.[65] For patients with risk factors for PPC, consideration of epidural anesthesia or intercostal nerve block should be considered when applicable.

NASOGASTRIC TUBE

Routine use of postoperative nasogastric tube (NGT) increases PPC including pneumonia and atelectasis, although on Cochrane review this trend was insignificant ($p = 0.07$).[66,67] We do not recommend routine postoperative NGT and employ this only in situations when worsening postoperative nausea, distention, or bilious vomiting develop due to postoperative ileus.

Bronchospasm

Bronchospasm in the postoperative setting may occur due to histamine release from perioperative medications, aspiration, and exacerbation of underlying pulmonary disease such as asthma or COPD. Management rests upon the identification of an underlying cause and treating it appropriately. Removal of offending drugs or allergens and addressing asthma or COPD with inhaled bronchodilators

represent first-line strategies.[68] For refractory cases, consider employing systemic steroids.

Atelectasis

Atelectasis commonly occurs following abdominal surgery, affecting patients in all ranges.[69,70] A consequence of surgical and anesthetic effects, atelectasis develops when dependent airways collapse, ultimately leading to changes in the compliance of lung tissue, decreased ventilation in these regions, and reduced movement of airway secretions.[71,72–74] These changes result in decreased oxygen exchange and increase respiratory effort and hypoxemia. In younger healthy patients, these changes may result in little to no clinical effect but may significantly alter the clinical course for patients with impaired lung function or comorbidities such as CHF.

Atelectasis develops in the early postoperative course with symptoms of hypoxemia typically becoming apparent approximately 48–60 hours following surgery and continuing for several days.[75,76] Hypoxemia that develops earlier than this time course (i.e., in the postanesthesia recovery unit) should prompt urgent investigation into alternative PPC including pneumothorax, upper airway edema, and anesthesia effects. Atelectasis in the postoperative setting is most commonly nonobstructive in nature and typically results from loss of contact between the parietal and visceral pleurae or compression of the lower and middle lobes, often due to pleural effusion.[77]

Within the appropriate clinical time course, atelectasis should be suspected when findings such as tachypnea, dyspnea, and hypoxemia are noted. Patients should be assessed for abundant sputum production and secretions, evident as rhonchi on auscultation or frequent productive cough. Obtaining a chest radiograph or chest computed tomography (CT) often confirms the diagnosis.[78]

Management of atelectasis through methods to reverse the process of lung volume collapse can prevent further PPC.[79] Strategies for managing atelectasis differ depending upon the level of airway secretions. For those without abundant secretions, implementation of supplemental oxygen, DBE, and IS remains the mainstay of initial management. Patients without secretions that remain hypoxic and with continued increased respiratory effort may benefit from positive airway pressure (CPAP). Squadrone et al. reported results of a randomized multicenter controlled trial of CPAP versus supplemental oxygen alone and demonstrated a decrease in intubation, pneumonia, and sepsis for patients receiving CPAP.[80] For patients with significant secretions, frequent chest physiotherapy and suctioning (nasogastric if the patient is not able to expectorate) should be implemented. In patients who fail to improve with these methods, consider pulmonary consultation for consideration of possible bronchoscopy and other techniques aimed to improve secretion clearance.[81,82]

Pleural Effusion

Limited data suggest that pleural effusion detected on chest radiograph occurs in up to 49% of patients' surgery when evaluated between 48 to 72 hours following abdominal surgery.[83] Pleural effusion appears to occur more commonly following upper abdominal surgery. Management of effusion is primarily conservative, as most of effusions resolve spontaneously. Pulmonary toilet with DBE and IS as well as early and frequent ambulation may serve to hasten resolution.

In the setting of persistent effusion or clinical concern, diagnostic evaluation of an effusion requires thoracentesis.[84] Thoracentesis can be performed at the bedside, and analysis can help establish diagnoses including malignancy, empyema, chylothorax, urinothorax, hemothorax, and infection.[85]

Postoperative Pneumonia

The incidence of postoperative pneumonia ranges from 1.5% to 50%, depending on a wide array of conditions including type of anesthesia, surgical details, and patient risk factors.[86,87] Postoperative pneumonia can present similarly to other conditions, such as atelectasis, pulmonary edema, and pulmonary embolism.[88] However, postoperative pneumonia requires accurate diagnosis as it is associated with mortality rates from 1.5% to 10%.[87,89]

Postoperative pneumonia should be considered in patients with fevers, increased white blood cell count, and chest imaging demonstrating new onset pulmonary infiltrates. Clinical symptoms of fever, tachypnea, dyspnea, and hypoxemia typically develop within the first five postoperative days.[90,91] Risk factors such as COPD, altered lung defenses, and active smoking should increase clinical suspicion.

Successful management of postoperative pneumonia requires accurate pathogen identification and appropriate antibiotics.[92] These infections, primarily nosocomial in origin, frequently result from resistant organisms, although multiple organisms may be identified. One study demonstrated that the most common pathogens were gram-negative bacteria (e.g., *Pseudomonas aeruginosa, Klebsiella pneumoniae, Acinetobacter* species), *Staphylococcus aureus,* and *Streptococcus pneumoniae.*[90] Prolonged intubation and exposure to antibiotics as well as COPD may increase risk for pneumonia due to organisms such as *Pseudomonas aeruginosa, Acinetobacter,* or methicillin-resistant *S. aureus* (MRSA).[93–96] Postoperative treatment requires accurate collection of respiratory culture and prompt empiric antibiotics.

Aspiration pneumonia during the postoperative period may result in patients with risk factors for decreased protection of their airways. These include neurologic disorders, impaired cough reflex, impaired mental status following surgery leading to dysfunctional swallowing, and postoperative vomiting. Introduction of gastric fluids or particulate matter into the lower airways may stimulate an inflammatory response and subsequent chemical pneumonitis, bacterial infection, or mechanical obstruction.[97–99]

Chemical pneumonitis occurs quickly after aspiration of gastric contents and may lead to dyspnea and respiratory distress.[100] Clinical symptoms include abrupt dyspnea, cyanosis, severe hypoxemia, and infiltrates on chest imaging. The inflammatory response may rapidly progress to acute respiratory distress syndrome (ARDS) and lead to respiratory failure.[101] As ARDS develops, inflammation of

the lung parenchyma results in systemic release of inflammatory mediators and frequently results in multisystem organ failure.[102] Treatment of ARDS involves mechanical ventilation, treatment of underlying causes, supportive care, and antibiotic coverage if indicated.

Gupta and colleagues have developed and validated a risk calculator for predicting postoperative pneumonia. This tool is available for free download at surgicalriskcalculator.com.[53]

Postoperative Management for Patients With Obstructive Sleep Apnea

More than half of patients with clinically important obstructive sleep apnea (OSA) present for surgery without formal diagnosis of OSA.[103,104] As the prevalence of obesity continues to rise, the rates of undiagnosed OSA in surgical patients will likely continue to increase.[105] As a result of the large number of patients that are undiagnosed, heightened vigilance for postoperative complications in patients with risk factors for OSA, such as obesity, should be considered.

Hypoventilation, periods of central apnea and upper airway obstruction combine to lead to rapid hypoxemia for patients with OSA. Consequently, careful monitoring of blood oxygen saturation both in the postanesthesia recovery unit, and also during postoperative hospital stays, is prudent. Patients who use CPAP at home should resume as soon as possible following surgery.[106,107] The evidence does not demonstrate a clear benefit for initiating CPAP in patients with OSA who have not used this preoperatively unless these patients are at high risk for PPC.[80] For patients demonstrating hypoxemia or hypoventilation following surgery, implementation of CPAP should be considered on an individual basis.

Complications Involving the Pleural Space

Injury involving the pleural cavity can occur during abdominal surgery, although risk is highest during surgery in the upper abdomen or upper retroperitoneum. These injuries occur both during open and laparoscopic procedures. Oftentimes violation of the pleural space is noted intraoperatively and should be suspected during laparoscopic surgery when excessive diaphragm motion, or billowing, is noted.[108] During open procedures, bubbling noted in the operative field may indicate an occult violation of the diaphragm and pleural cavity. Occult injuries should be considered when hypoxemia or dyspnea is discovered in the postanesthesia recovery unit. However, clinical manifestation of pleural space injury is variable, ranging from an asymptomatic small apical pneumothorax to a large tension pneumothorax that may lead to hemodynamic instability.

PNEUMOTHORAX

Gas may enter the pleural cavity through several routes. These range from patent congenital diaphragm defects to direct injuries to the diaphragm, chest wall, or via musculofascial planes of the diaphragm and mediastinum during insufflation with carbon dioxide (CO_2).[109,110] The volume of gas that enters the pleural cavity determines the degree of pneumothorax (PTX). Small amounts of gas often do not increase the pressure in the pleural cavity above atmospheric pressure, and thus clinical symptoms may not develop. Often these PTX are detected on chest radiograph and do not demonstrate mediastinal shift or represent clinically significant entities.[111] As the amount of gas increases, the pressure in the affected pleural space increases above atmospheric pressure, eventually compressing the ipsilateral lung. Mediastinal shift to the contralateral hemithorax and flattening of the ipsilateral hemidiaphragm are classically noted on radiograph.

Reported rates of PTX following urologic surgeries range from 0.6% to 25%.[112–116] The rates for PTX following laparoscopic surgeries appear lower (0.6% to 8.5%).[112,114–116]

Management of PTX begins with clinical suspicion. When noted intraoperatively, the anesthesiologist should be informed to confirm hemodynamic and respiratory stability. Once established, repair of diaphragm injury should be performed using running, absorbable suture. Prior to closure of this suture, a red rubber catheter can be introduced into the pleural space with its distal end submerged under water or saline. The anesthesiologist then ventilates the patient in order to evacuate gas from the pleural space via the catheter until no further bubbles are noted from the red rubber catheter. The catheter is removed when the diaphragm suture is tied down.[117] This approach can be performed with equal effectiveness for both open and laparoscopic procedures and is necessary when repairing diaphragmatic incisions used during thoraco-abdominal approaches. In the case of a diaphragmatic excision due to malignancy, successful mesh replacement of the diaphragmatic defect secured with nonabsorbable sutures has been reported.[117]

Despite the low rates of these injuries, clinical suspicion for occult injury should remain. Postoperative hypoxemia or dyspnea should be investigated with chest radiography. If central venous catheterization was performed for intraoperative fluid management, postoperative chest radiography should be performed. Routine use of postoperative chest imaging may identify small PTX without clinical sequelae.[111] These can be safely managed conservatively and followed with serial chest radiograph. In the event that a large PTX is noted, management with a tube thoracostomy is recommended.

CHYLOTHORAX

Chyle accumulation within the pleural space is a rare complication. Case reports describe chylothorax following retroperitoneal surgeries; however, these occur in conjunction with chylous ascites and subsequent communication into the pleural space.[116,118] Management includes diagnosis through thoracentesis and treatment of the underlying lymph leakage. Successful pleural space drainage and sclerotherapy have been reported.[118]

HEMOTHORAX

Accumulation of blood within the pleural space following urologic surgery is also a rare complication, with only a few

case reports available. Abreu et al. report one case (0.08%) in their review of 1129 patients undergoing laparoscopic urologic surgery.[116] In this case, an intercostal artery was injured, and repair required emergent open thoracotomy. Additional case reports describe hemothorax following laparoscopic pyeloplasty, laparoscopic cryoablation of renal masses, and percutaneous nephrolithotomy.[119–121] Management requires identification of the bleeding source and possible tube thoracostomy.

HYDROTHORAX

Iatrogenic instillation of irrigation fluid into the pleural space may result in hydrothorax. Hydrothorax has been reported as a complication following percutaneous nephrolithotomy.[122,123] Supracostal percutaneous nephrolithotomy may result in higher risk than standard approaches.[122] Management may require tube thoracostomy. For additional discussion of hydrothorax, please refer to the section below regarding percutaneous nephrolithotomy.

Pulmonary Embolism

Pulmonary embolism (PE) results from venous thromboembolism (VTE) and is a potentially fatal pulmonary complication. Prior to use of VTE prophylaxis, studies estimated the incidence of deep vein thrombosis (DVT) in hospitalized patients to range between 10% and 80%, with fatal PE ranging from 0.1% to 7% in patients undergoing elective surgery.[124] While DVT prophylaxis has decreased these rates, VTE and PE remain serious postoperative complications.

Risk for postoperative patients varies depending upon multiple factors.[124–127] Significant risk factors include age, prior VTE, history of malignancy, obesity, and hypercoaguable state (e.g., Factor V Leiden) as well as medical comorbidities. The American College of Chest Physicians provides guidelines to risk stratify surgical patients.[128] Many urologic procedures fall into the moderate risk or higher categories.

Strategies for prevention of VTE aim to decrease risk of subsequent PE. Nonpharmacologic approaches employ frequent, early ambulation, compression stocking, and pneumatic compression devices and may be sufficient for patients who are very low or low risk. In patients who are moderate or higher risk, including pharmacologic prophylaxis is preferred. Pharmacologic prevention must be balanced with potential for bleeding complications in the perioperative period. Options for pharmacologic prevention include unfractionated heparin, low-molecular-weight heparin, fondaparinux, and novel oral antithrombotic agents (e.g., rivaroxaban, dabigatran, apixaban). Regional and spinal anesthesia should be considered for higher risk patients undergoing lower abdominal or pelvic urologic procedures as these have been associated with a decreased risk of PE when compared with general anesthesia.[129]

The clinical presentation of PE is varied and nonspecific. Patients may be asymptomatic but may also experience sudden shock and death.[130] The most common symptoms of PE, according to two large prospective studies, are dyspnea (73%), pleuritic chest pain (44%), cough (37%), orthopnea (28%), calf/thigh pain/swelling (44%), wheezing (21%), and hemoptysis (13%).[130] Despite these clinical indicators, patients with large PE may report mild or no symptoms.[130–132] The most common clinical signs include tachypnea (54%), calf/thigh swelling/edema/erythema (47%), tachycardia (24%), and rarely fever (3%). Unfortunately, given the nonspecific nature of this clinical presentation, the sensitivity and specificity for PE on clinical evaluation are 85% and 51%, respectively.[133]

Clinical suspicion for PE in the postoperative phase prompts urgent investigation. Multiple clinical calculators may assist with stratifying patients to empiric therapy.[134–136] For the majority of patients with suspicion for PE, the preferred diagnostic study is a computed tomographic pulmonary angiogram (CTPA).[130,137] For patients unable to undergo CTPA, ventilation/perfusion (V/Q) scan remains a sensitive but poorly specific test that can be obtained. In addition, lower extremity duplex ultrasound should be obtained to assess for presence of DVT, and, if found, anticoagulation should be initiated.

Once clinical evaluation confirms suspicion for DVT or PE, empiric anticoagulation should be promptly initiated. In postoperative patients anticoagulation may result in bleeding. Absolute contraindications to heparin therapy are active bleeding, severe bleeding diathesis, a platelet count $\leq 20{,}000/mm^3$, neurosurgical or ocular surgical procedures performed within the past 10 days, or intracranial bleeding within the past 10 days.[138] In essence these contraindications to anticoagulation serve as indications for placement of an IVC filter. Consideration may also be given to placement of an IVC filter in the setting of recurrent PE while therapeutic on anticoagulation or when bleeding risk outweighs risk of DVT or PE such as poor cardiopulmonary reserve.

If PE embolism results in hemodynamic instability, more aggressive treatment with thrombolytic therapy is indicated. Thrombolytic therapy should also be considered when patients are at high risk of bleeding from systemic anticoagulation or if systemic anticoagulation fails. Finally, for hemodynamically unstable patients who are not candidates for thrombolytic therapy, embolectomy via either catheter-based approaches or open surgical approaches may be warranted.

It is our practice to administer unfractionated heparin preoperatively (5000 units subcutaneously administered prior to surgery) and throughout the perioperative period for all patients undergoing pelvic surgery for urologic malignancy. This practice is also applied to patients undergoing retroperitoneal oncologic surgery when bleeding risk is deemed acceptable.

Air Embolism

Introduction of insoluble gas into the vasculature system is a rare but dangerous event. Amongst urologic procedures, laparoscopic procedures carry the highest risk for this complication.[139–142] Gas may gain entry into open vasculature via any vascular invasion, surgical or traumatic, within the pleural or peritoneal cavity as well as through endoscopic approaches. Venous air emboli have been reported following retrograde pyelogram, transurethral resection of the prostate, percutaneous nephrostomy tube placement,

and percutaneous nephrolithotomy as well as open radical prostatectomy and laparoscopic prostatectomy.[143–150] Additionally, case reports describe gas embolism following sexual intercourse, autoerotic exercises, and following urethral insufflation.[151–155]

Air or gas embolism occurs when insoluble gas enters an open venous or arterial channel with sufficient pressure differential to allow for gas entry into the vascular system. Gas emboli should be considered in appropriate clinical situations (trauma, laparoscopic surgery, neurosurgery, central venous catheterization) when patients experience sudden onset respiratory distress or neurologic decompensation. However, there are no clear clinical indicators to differentiate gas emboli from other potential complications including pulmonary emboli, myocardial infarction, stroke, and other acute adverse events.

When gas emboli are suspected, the optimal diagnostic test is transthoracic echocardiography (TTE) followed by CTPA.[156,157] When the diagnosis is suspected, patients should be immediately positioned into left lateral decubitus position (Durant's maneuver) or Trendelenburg for suspected venous emboli or supine for suspected arterial emboli. These positioning maneuvers aim to contain the gas emboli.[158] Once the diagnosis has been confirmed, management options range from hyperbaric oxygen, manual aspiration of air from the right ventricle via central venous catheter, or, as a last resort, chest compressions.[159–162]

Pulmonary Complications of Open and Laparoscopic Urologic Surgery

Pleural space violation during surgical procedures in the flank and upper abdomen may occur due to the fact that the pleura extends down to the 11th rib in the posterior axillary line and to just below the 12th rib in the area of the vertebral column.[163] At times, pleural space entry is planned for flank or thoraco-abdominal incision. In addition, upper pole renal tumors have been reported involving or invading the diaphragm.[117,164] As noted above, upper abdominal and flank surgical procedures are associated with a risk of pleural injury and pneumothorax.[165,166] Modifications of the traditional flank incision, such as the supra-11th mini-flank incision, help to prevent pleural injury during open surgical procedures of the kidney.[167]

Pleurotomies recognized intraoperatively during open and laparoscopic surgical procedures can usually be repaired without difficulty or sequelae.[113] A 12Fr rubber catheter is initially placed through the defect and into the pleural cavity, and the pleura is closed with absorbable suture in a running pattern. The lung is then expanded with positive pressure ventilation by the anesthesiologist, removing the remaining gas within the pleural cavity through the end of the catheter. Once all gas has been expelled, the catheter is removed, and the running suture is tied while the lung remains expanded.

Suspected diaphragmatic tears during laparoscopy should be repaired primarily, if possible. Depending on the severity of the injury and the clinical status of the patient, these repairs can be performed either immediately or when the primary operation has been completed. Delaying repair until after specimen extraction may provide better visualization of the injury; however, unstable patients require immediate attention to this complication. If repair can be delayed, then it is advised to decrease the pneumoperitoneum to 10 mm Hg to limit the extent of any present pneumothorax, to facilitate patient ventilation, and to allow for tension-free anastomosis.[168] A thoracostomy tube is indicated for pleural hemorrhage, lung injury, or inability to primarily close the diaphragm.[115]

It is our practice to obtain routine postoperative chest radiograph, although this is up to surgeon discretion. Several studies recommend that postoperative chest radiographs are obtained following cases involving central line placement, intraoperative diaphragm injury, postoperative respiratory distress, or abnormal postoperative clinical findings.[169,170]

Pulmonary Complications of Percutaneous Nephrolithotomy

Pulmonary injuries following percutaneous nephrolithotomy (PCNL) occur during the percutaneous access. Pleural complication rates have been reported to range from 2.3% to 23%, depending on the definition of injury.[171–175]

Rates of PPC are higher with the supracostal PCNL, with a reported 16-fold greater risk of pleural injury when access is above the 12th rib.[176,177] While an infracostal approach is associated with fewer PPC, a supracostal puncture improves stone access and clearance for certain situations (e.g., scoliosis, upper calyx stone).[178] Supracostal punctures should be performed using C-arm fluoroscopic guidance and following maximal exhalation.[179,180] In addition, utilization of an adequately sized working sheath and maintaining low pressure saline irrigation minimize entry of gas and fluid into the pleural space.[176]

The incidence of pulmonary complications that necessitate surgical intervention after a supra-12th rib approach ranges from 3% to 23%.[179,181] Intraoperative placement of an 8 to 10Fr loop nephrostomy tube into the pleural space under fluoroscopic guidance for significant hydropneumothorax following supracostal PCNL may obviate the need for a traditional thoracostomy tube insertion.[182] Traditional thoracostomy tube placement is recommended for when parenchymal injury is suspected or significant drainage of fluid or blood is required.

Nephropleural fistula is a rare pulmonary complication of PCNL and may present as urinothorax. Rates of nephropleural fistula range from 2.3% for supra-12th rib approaches to 6.3% for supra-11th rib access.[183] Management involves collecting system decompression with ureteral stent and concomitant thoracostomy tube. Refractory cases may require decortication with pleural sclerosis.

Patients With Prior Bleomycin Chemotherapy

Men with a history of testicular cancer may have been exposed to chemotherapy regimens including bleomycin, an antibiotic with antineoplastic activity. Often, men with

poor-risk or intermediate-risk testicular cancer are subjected to bleomycin.

Patients exposed to bleomycin are at risk for developing bleomycin-related toxicities, which include interstitial pneumonitis (bleomycin-induced pneumonitis [BIP]). The pathophysiology of this toxicity is multifactorial and is related to cumulative bleomycin exposure, age, thoracic radiation, renal insufficiency, tobacco use, and exposure to high oxygen concentration.[184] Pulmonary fibrosis can develop in 2–40% of those who develop BIP.[185] Symptoms of BIP include cough, dyspnea on exertion, and fever. These symptoms often begin gradually but may manifest as late as 6 months following discontinuation of therapy. In some cases, symptoms progress to worsening respiratory failure.[186]

Patients with a history of bleomycin exposure should undergo pulmonary function testing prior to elective surgical procedures. Management of these patients requires careful perioperative fluid managements and minimization of exposure to high concentration oxygen.[187,188]

Conclusion

Postoperative pulmonary complications occur at a similar frequency and result in similar rates of morbidity and mortality as cardiovascular complications. The most important patient-related factor that should be considered by the urologist when assessing preoperative risk is patient age, although COPD, CHF, and cigarette smoking also increase risk. Many urologic procedures involve risk for PPC, and thus elevated vigilance in the perioperative period is recommended. Venous thromboembolism prophylaxis should be utilized whenever possible.

References

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Chapter 2 Questions

1. Which of the following patient characteristics has not been shown to confer an increased risk of postoperative pulmonary complications?
   a. Chronic lung disease
   b. Age over 50
   c. Obesity
   d. Cigarette smoking
   e. Congestive heart failure

2. Which of the following risk factors is the most important when considering risk for development of postoperative pulmonary complications?
   a. Chronic obstructive pulmonary disease
   b. Surgical site
   c. Surgical time
   d. Preoperative anemia
   e. General anesthesia

3. Evidence suggests that cigarette smokers who quit 1 week prior to surgery appear to experience an increased risk for postoperative pulmonary complications (PPCs) due to which of the following mechanisms?
   a. Elevated carbon monoxide levels
   b. Elevated nicotine levels
   c. Increased airway reactivity
   d. Increased sputum production
   e. All of the above

4. Which of the following postoperative interventions may increase risk of postoperative pulmonary complications?
   a. Nasogastric tube
   b. Epidural anesthesia
   c. Deep breathing exercises
   d. Intercostal nerve block
   e. Chest physical therapy

5. A healthy 49-year-old male underwent a right robotic partial nephrectomy. The patient is noted to be awake, alert, and comfortable with normal heart rate and blood pressure. However, PACU oxygen saturation is noted to be 89% on room air, which improves to 94% on 2 L nasal cannula oxygen. He reports a productive cough and mild dyspnea. Which of the following conditions is least likely the cause of his hypoxemia?
   a. Pneumothorax
   b. Atelectasis
   c. Pulmonary embolism
   d. Airway edema
   e. Bronchospasm

6. When venous air embolism is suspected, which of the following maneuvers should be performed first?
   a. Closed-chest cardiac massage
   b. Air aspiration via central venous catheter
   c. Position the patient in left lateral decubitus position
   d. Position patient in sitting position
   e. Position the patient in a supine position

7. Which of the following mechanisms is most likely responsible for hemothorax after percutaneous cryoablation of the kidney?
   a. Direct contact of the "ice ball" with the posterior surface of the diaphragm
   b. Inadvertent laceration of the superior epigastric artery
   c. A secondary consequence of postprocedure atelectasis
   d. Injury to the phrenic or subcostal arteries that run along the lower border of the 12th rib
   e. All of the above

8. During a left-sided robotic partial nephrectomy, the diaphragm is noted to billow with each ventilation. Which of the following features necessitates insertion of a tube thoracostomy?
   a. Intraoperative inspection reveals injury to the lung parenchyma
   b. Intraoperative inspection reveals 2 cm laceration of the diaphragm
   c. Irrigation fluid is noted within the pleural space via diaphragmatic injury
   d. Intraoperative inspection reveals 6 cm laceration of the diaphragm
   e. None of the above

9. A 45-year-old male presents with fever, dyspnea, tachycardia, and urinothorax following supra-12th rib PCNL for a staghorn stone. Which of the following procedures should be initially considered in the management of this complication?
   a. Tube thoracostomy
   b. Pleurodesis
   c. Left ureteral stent insertion
   d. A and C
   e. All of the above

10. A 65-year-old woman with a history of diabetes and a BMI of 38 undergoes an uncomplicated cystocele repair. She is noted to be hypoxic in the postanesthesia care unit. She otherwise has no symptoms and the remainder of her clinical evaluation is unremarkable, and a chest radiograph is normal. Which of the following interventions should be initially be considered?
    a. CT chest with IV contrast
    b. Supplemental oxygen and continued pulse oximetry
    c. Continuous positive airway pressure (CPAP)
    d. Empiric anticoagulation
    e. Chest physical therapy

Answers

1. **c.** Evidence does not demonstrate an increase in pulmonary complications associated with obesity. Obesity does confer an increased risk in venous thromboembolic complications such as deep vein thrombosis, which may lead to pulmonary embolism and is thus a critical risk factor requiring clinical assessment.

2. **b.** The most important individual risk factor for postoperative pulmonary complication is the surgical site and location. High-risk surgical procedures present significant risk for complications even in young and healthy patients. Special consideration should be taken for surgical approaches involving, or near, the diaphragm.
3. **e.** The pathophysiology on lung function in the first 2 weeks following smoking cessation involves elevated carbon monoxide and nicotine levels that decline within the first week. Airway reactivity also begins to reduce after 1 week of cessation. Sputum volume increased in the initial 2 weeks following cessation and begins a steady decline over the next 6 weeks.
4. **a.** Nasogastric tube placement as a routine postoperative procedure has been widely employed to speed recovery of bowel function, decrease risk to GI anastomoses, and decrease risk of ileus. Several studies have demonstrated increased PPC associated with nasogastric tube (NGT) use; however, a Cochrane review demonstrated an insignificant increase in PPC associated with routine NGT use ($p = 0.07$).
5. **b.** Patients who develop acute postoperative hypoxemia are more likely experiencing an acute postoperative pulmonary complication and should be evaluated accordingly. Postoperative atelectasis typically develops on postoperative days 2–4.
6. **c.** Durant's maneuver should be performed immediately when venous air embolism is suspected. This position aims to trap the gas embolus into the right ventricle and decrease risk of passage further into the pulmonary vasculature. Alternatively, the patient can be put in a left lateral decubitis position with the head down or in Trendelenburg position. Patients with suspected arterial gas emboli should be placed in the supine position.
7. **d.** Injury to the phrenic or subcostal arteries during percutaneous procedures may result in hemorrhage through the probe tract and into the pleural space. Pleural effusions or atelectasis is commonly an exudate, and "ice ball" contact with the diaphragm frequently results in transudates, which are nonblood effusions.
8. **a.** Intraoperative diaphragmatic injuries or pleurotomies should be suspected when the "floppy diaphragm" is noted. Attempts should be made to primarily close these injuries intraoperatively, either after completion of resection or prior, depending on the clinical situation. There is no size limitation to primary closure of the pleurotomy. Tube thoracostomy is necessary when injury to lung parenchyma is noted, the pleurotomy cannot be closed primarily, or significant hemorrhage is noted in the pleural space. Fluid in the pleural space can be evacuated safely with suction or via a catheter placed into the pleural space.
9. **d.** Nephropleural fistula is a rare complication of percutaneous nephrolithotomy (PCNL) and occurs more frequently following supra-12th rib access. Use of low-pressure saline irrigation and a large percutaneous sheath may help decrease the likelihood of this complication. Initial management includes tube thoracostomy and collecting system decompression with ureteral stent. In refractory cases, pleurodesis may be necessary.
10. **b.** The rate of undiagnosed obstructive sleep apnea has been steadily increasing and mirrors rising rates of obesity. Patients with obstructive sleep apnea are prone to rapid desaturation and upper airway obstruction, which may manifest itself in the postanesthesia recovery unit. Current guidelines include preoperative screening for obstructive sleep apnea and close monitoring of those with clinical signs and symptoms. CPAP appears to be useful for patients who are using this at home and should be implemented in patients with suspected obstructive sleep apnea and signs of dyspnea, respiratory effort, or hypoxemia that does not respond to supplemental oxygen.

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3 Preoperative Cardiac Assessment and Management of Perioperative Cardiac Complications

ALAN SHAH

CHAPTER OUTLINE

Introduction
Timing and Surgical Risk
Evaluating the Patient and Risk Stratification
Coronary Artery Disease
Preoperative
Postoperative
Congestive Heart Failure
Preoperative
Postoperative
Valvular Heart Disease
Preoperative
Postoperative
Arrhythmias
Preoperative
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Cardiovascular Implantable Electronic Devices
Preoperative
Postoperative
Pulmonary Hypertension
Preoperative
Postoperative
Perioperative Medical Interventions
Chapter 3 Questions and Answers

KEY POINTS

1. A careful history and physical examination may identify underlying cardiac disease.
2. Patients with coronary artery stenting should have close coordination between the cardiology consultant and surgical team in order to determine appropriate antiplatelet therapy management.
3. Patients with decompensated congestive heart failure have an increased operative risk and should be medically optimized prior to surgery.
4. Patients with valvular heart disease should be evaluated for changes in their clinical status. Transvalvular aortic valve replacement is an option available for severe aortic stenosis in certain patients.
5. Patients with unstable cardiac arrhythmias should be treated prior to surgery.
6. A wide variety of cardiac implantable electronic devices are available. An appropriate prescription for perioperative management of the device should be established prior to surgery.
7. Patients with pulmonary hypertension should be managed by experts perioperatively.

Introduction

Careful perioperative evaluation of a patient undergoing surgery combines clinical assessment with current clinical practice guidelines (CPG). The CPGs translate scientific evidence into guidelines that standardize cardiovascular care. These guidelines assess the strength and quality of evidence using evidence-based methodologies[1]. Defining the patient's perioperative risk in the context of CPGs and communicating this with the patient, surgeon, anesthesiologist, and other caregivers is essential. Using this approach, the patient and surgical team can understand the perioperative cardiovascular risk in the context of the anticipated surgery.

In 2014, the Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery was updated[2]. This guideline combined with other disease specific CPGs and statements provide the reference for this chapter.

Timing and Surgical Risk

It is important for the cardiology consultant to understand the timing and risk of a surgery. An *emergency* surgery is required within six hours when life or limb is threatened. An *urgent* procedure will need to be performed within 6 to 24 hours. This will allow for a limited evaluation and optimization of the patient's risk factors. A *time-sensitive* procedure, >1 week to 6 weeks, will allow for evaluation and management of a patient in order to avoid potential complications. An elective procedure can be delayed for up to one year[2] (Table 3.1).

A *low risk procedure* is when the combined surgical patient characteristics have a <1% risk of major adverse cardiac event (MACE) of death or myocardial infarction (MI). A ≥1% MACE is considered an elevated risk procedure[2].

Table 3.1 Timing of Surgery

Definition	Time
Emergency	<6hours
Urgent	6-24 hours
Time-Sensitive	1-6 weeks
Elective	Up to 1 year

Evaluating the Patient and Risk Stratification

Defining the patient's clinical risk factors is the first step in risk assessment. Clinical risk factors include: coronary artery disease (CAD), congestive heart failure (CHF), valvular heart disease (VHD), arrhythmia and conduction disorders, cardiovascular implantable electronic devices (CIED), and pulmonary vascular disease.

The 2014 ACC/AHA Perioperative Clinical Practice Guideline outlines a stepwise approach for perioperative cardiac assessment for CAD[2] (Fig. 3.1). For emergent surgeries, the patient should proceed directly to the operating room. In elective or time sensitive procedures, patients with acute coronary syndromes (ACS), symptomatic arrhythmias, new exacerbation of CHF, or symptomatic valvular disease should be managed according to the appropriate CPG prior to surgery.

For patients who are otherwise stable, there are several risk stratification tools available to estimate the perioperative risk. The Revised Cardiac Risk Index (RCRI) incorporates high-risk surgery (intraperitoneal, intrathoracic, or suprainguinal vascular), history of ischemic heart disease, history of CHF, history of cerebrovascular disease, history of diabetes requiring preoperative insulin, and preoperative creatinine ≥ 2 mg/dl to establish a perioperative risk[3]. The rates of complication in patients with 0, 1, 2, or ≥3 risk factors are 0.4%, 0.9%, 7%, and 11% respectively. The American College of Surgeons NSQIP MICA risk prediction

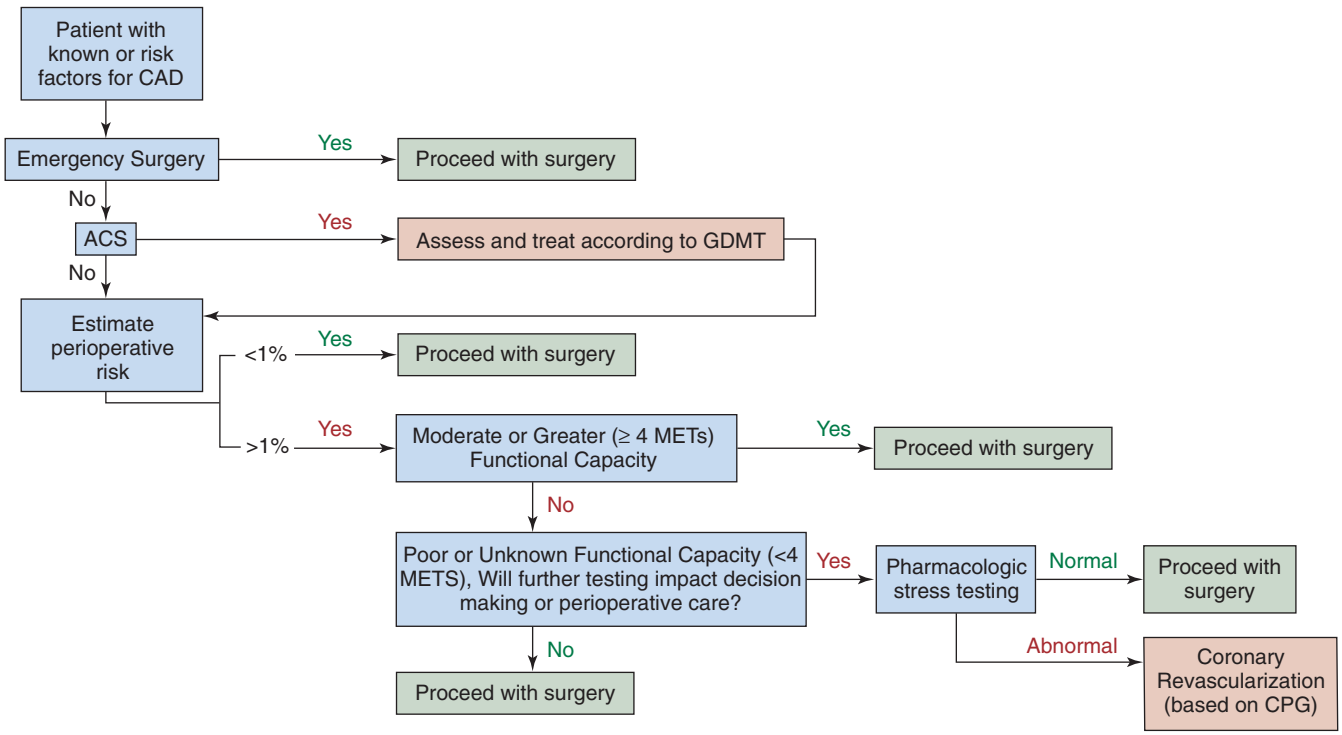


Figure 3.1 Approach to Perioperative Assessment of CAD. CAD, coronary artery disease; ACS, acute coronary syndrome; GDMT, guideline-directed medical therapy; MET, metabolic equivalents; CPG, clinical practice guidelines. (Modified from Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol. 2014;64:e77-e137.)

rule incorporates different surgical sites and predicts the risks for cardiac arrest or myocardial infarction (MI) (http://www.surgicalriskcalculator.com/miorcardiacarrest)[4]. The American College of Surgeons NSQIP Surgical risk calculator uses the current procedural terminology code along with 21 specific patient variables (http://riskcalculator.facs.org/)[5].

Patients with a perioperative risk < 1% can usually proceed to surgery without any further risk stratification. Patients with a perioperative risk ≥ 1% should have an assessment of their functional capacity. Functional capacity is expressed in terms of metabolic equivalents (METs). One MET is the resting oxygen consumption for a 70 kg, 40-year-old male. An excellent functional capacity, defined as > 10 METs, includes strenuous sports such as singles tennis or basketball. Good functional capacity, 7-10 METs, includes activities such as jogging. Moderate functional capacity, 4-6 METs, includes heavy housework, climbing a flight of stairs, walking up a hill, or walking for 4 miles per hour (mph) on a level surface. Examples of poor functional capacity, ≤4 METs, include walking at 2-3 mph or light housework (Table 3.2). Patients who have a moderate or excellent functional capacity can proceed with surgery without any further testing. Patients with an unknown or poor functional capacity undergoing high-risk surgery may require further cardiac testing if the results will change management. Patients with a poor exercise tolerance have a higher incidence of perioperative complications[6].

Table 3.2 Estimated Energy Requirements for Various Activities

	Can you …		Can you …
1 MET	Take care of yourself?	4 METs	Climb a flight of stairs or walk up a hill?
	Eat, dress, or use the toilet?		Walk on level ground at 4 mph (6.4 kph)?
	Walk indoors around the house?		Run a short distance?
	Walk a block or 2 on level ground at 2–3 mph (3.2–4.8 kph)?		Do heavy work around the house such as scrubbing floors or lifting or moving heavy furniture?
4 METs	Do light work around the house like dusting or washing dishes?		Participate in moderate recreational activities like golfing, bowling, dancing, playing doubles tennis, or throwing a baseball or football?
		>10 METs	Participate in strenuous sports like swimming, singles tennis, football, basketball, or skiing?

kph, kilometers per hour; MET, metabolic equivalent; mph, miles per hour. (Modified from Hlatky MA, Boineau RE, Higgenbotham MB, et al. A brief self-administered questionnaire to determine functional capacity (the Duke Activity Status Index). Am J Cardiol. 1989;64:651-654.)

Coronary Artery Disease

PREOPERATIVE

A MI that occurred within six months of planned noncardiac surgery is considered recent[2]. Data shows that the rates of postoperative MI decreased as the length of time from the cardiac event to surgery increased[7]. Surgery should take place at least 60 days after the last cardiac event[2]. Furthermore, the patient's age also plays an important role. Patients over 55 years of age have a greater prevalence of cardiac risk factors which increases their overall risk for MACE[2]. Patients over the age of 65 have an increased risk of acute ischemic stroke undergoing noncardiac surgery[8].

Routine revascularization prior to noncardiac surgery to reduce perioperative cardiac events is not recommended[2]. The Coronary-Artery Revascularization before Elective Major Vascular Surgery trial demonstrated that revascularization before elective major vascular surgery does not improve long-term survival[9]. Furthermore, there was no significant reduction in MACE postoperatively. In this trial, patients with clinically significant, stable coronary disease were randomized to undergo coronary revascularization or medical therapy. Patients were carefully screened and those with coronary artery disease not amenable to revascularization, ≥ 50% stenosis of the left main coronary artery, left ventricular ejection fraction <20%, and severe aortic stenosis (AS) were excluded.

Indications for revascularization prior to surgery include: high risk coronary anatomy such as left main disease, unstable angina, MI, or arrhythmias that are ischemic in origin. Patients who require revascularization prior to surgery should be treated according to the CPG for coronary artery bypass grafting (CABG)[10] or percutaneous intervention (PCI)[11].

In patients who underwent a drug eluting stent (DES) who now require surgery, the decision to continue aspirin or dual antiplatelet therapy (DAPT) should be individualized. DAPT includes an aspirin and a $P2Y_{12}$ platelet receptor-inhibitor, which includes clopidogrel, prasugrel, and ticagrelor. Non-operative risk factors for DES thrombosis include: premature discontinuation of DAPT, diabetes, renal failure, low ejection fraction, advanced age, and procedural characteristics. These include type of DES, bifurcation and ostial lesions, long stent length, multiple stents, overlapping stents, small-diameter vessels and suboptimal results such as coronary dissection or under expansion[12]. In the operative setting, multiple factors such as coronary vasospasm, activation of inflammatory pathways, increase in catecholamine secretion, reduction in tissue plasminogen activator, and increased platelet activation and shear stress may also lead to acute stent thrombosis.

In the nonoperative setting, the rates of stent thrombosis with newer-generation DES is low[13]. Several trials have shown that there was no significant difference in the rates of stent thrombosis in patients treated with 3 to 6 months of DAPT as compared to patients treated with longer durations[13]. In the operative setting, studies showed that the risk of stent thrombosis is greater when the surgery is performed soon after stent implantation. The risk of thrombosis was 3.5% within 6 weeks of stent (BMS and first generation DES stents- sirolimus and paclitaxel) implantation and 1% at 6

Table 3.3 Antiplatelet Management in Patients With PCI

Balloon Angioplasty	Delay surgery for at least 14 days (Class I)
BMS stent	<30 days, Delay surgery for at least 30 days, continue ASA (Class I) ≥30 days, Proceed with surgery
DES stent	<3 months, Delay surgery 3-6 months, Proceed based on risk vs. benefits (Class IIb) >6 months, Proceed with surgery (Class I)

PCI, percutaneous coronary intervention; BMS, bare metal stent; DES, drug eluting stent; ASA, aspirin.

(Adapted from Figure 6 Levine GN, Bates ER, Bittl JA, et al. 2016 ACC/AHA Guideline Focused Update on Duration of Dual Antiplatelet Therapy in Patients with Coronary Artery Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol. 2016;68:1082-1115.)

and 24 months[14]. In a meta-analysis of 839 patients with DES, 2.3% had stent thrombosis within six months of implantation, 1.7% within 6 to 12 months, and 0.86% >12 months after implantation[15].

The 2016 ACC/AHA Guideline Focused Update on Duration of Dual Antiplatelet Therapy in Patients with Coronary Artery Disease has updated the recommendations of DAPT perioperatively[13]. The decision on timing of surgery and DAPT therapy involve the type of surgery, risk of delaying the surgery, risk of stent thrombosis and ischemia, and the risk of bleeding. In situations where noncardiac surgery needs to be performed urgently, balloon angioplasty may be required and surgery should be postponed for at least 14 days[2]. Patients who had recent BMS stent implantation, surgery should be delayed for at least 30 days. Patients with DES placed within the first 3 months should have their surgery delayed. Proceeding with surgery within the first 3 to 6 months may be considered if the risk of delaying surgery is greater than the risk of stent thrombosis (Class IIb).[13] Patients with DES implanted ≥ 6 months can proceed with surgery (Class I)[13] (Table 3.3).

In those situations where discontinuation of $P2Y_{12}$ platelet receptor-inhibitor therapy is required, aspirin should be continued if surgically feasible. The risk of bleeding with DAPT therapy is most likely to be higher than aspirin alone or no antiplatelet therapy but the degree of increase is currently unclear[2]. Clopidogrel[16] and ticagrelor[17] should be stopped 5 days prior to surgery, and prasugrel should be stopped 7 days prior to surgery[18]. Restarting $P2Y_{12}$ platelet receptor-inhibitor therapy should be done as soon as the patient is surgically stable[2].

POSTOPERATIVE

Perioperative MI is a common complication of major noncardiac surgery. A perioperative MI increases the risk of cardiac morbidity and mortality[19,20]. Myocardial infarction can be diagnosed based on clinical symptoms, electrocardiographic (ECG) findings, measurement of biomarkers, and imaging. The Third Universal Definition of an MI is defined as detection of a rise and/or fall of cardiac biomarkers with at least one value above the 99th percentile upper reference limit and with at least one of the following: 1) symptoms of ischemia; 2) new or presumed new significant ST-segment-T-wave changes or new left bundle branch block (LBBB); 3) development of pathological Q waves in the ECG; 4) imaging evidence of new loss of viable myocardium or new regional wall motion abnormality; and, 5) identification of an intra-coronary thrombus by angiography or autopsy[21].

Patients with a perioperative MI and myocardial injury that do not fulfill the Third Universal Definition of a MI[21] have a worse short and long-term outcome[19,20,22]. Myocardial infarction is classified in five categories. A spontaneous MI (Type 1) is due to atherosclerotic plaque rupture resulting in intraluminal thrombus[21]. A Type 2 MI is due to an ischemic imbalance. Myocardial injury with necrosis occurs when the demand for myocardial oxygen is greater than the supply. Cardiac death due to myocardial infarction is classified as Type 3. Type 4 and 5 are related to peri-procedural injury in the setting of PCI or CABG respectively. While most perioperative MIs are usually Type 2, clinicians should be vigilant for Type 1 MIs.

Biomarkers of cardiac necrosis include cardiac troponin (T or I) or the MB fraction of creatinine kinase. It is important to distinguish between a rise and/or fall of biomarkers from a chronic elevation. Blood samples should be drawn on first assessment and then repeated 3-6 hours later. The measurement of troponin levels is recommended in the setting of signs or symptoms suggestive of myocardial ischemia or MI (CIass I)[2]. The routine use of biomarkers in patients without signs or symptoms suggestive of myocardial ischemia or MI is not recommended (Class III).

ECG manifestations of acute MI (Figs. 3.2 and 3.3) are defined as: 1) new ST elevation at the J point in 2 continuous leads with the cut-point ≥1 mm in all leads other than leads V2-V3. These leads require ≥ 2 mm in men ≥40 years, ≥ 2.5 mm in men <40 years, or ≥ 1.5 mm in women[21]. In patients with a concern for left circumflex ischemia, leads can be positioned in the left posterior axillary line (V7), left mid-scapular line (V8), and the left paraspinal border (V9). In patients with a suspected inferior or right ventricular infarction, leads can be placed in the right V3 and V4 positions. In addition, ST depression in ≥2 precordial leads (V1–V4) may indicate transmural posterior injury. Multilead ST depression with coexistent ST elevation in lead aVR has been described in patients with left main or proximal left anterior descending artery occlusion[23]. In addition, patients may also present with a new LBBB. In those patients with an existing LBBB, the Sgarbossa criteria can be used: 1) ST-elevation ≥1 mm and concordant with QRS complex (5 points); 2) ST segment depression ≥ 1 mm in lead V1, V2 or V3 (3 points); and, 3) ST-elevation ≥ 5 mm and discordant with QRS complex (2 points). A score of more than 3 points has a 98% specificity[24].

With the exception of a true posterior myocardial infarction, the absence of persistent ST-elevation is suggestive of non-ST segment acute coronary syndrome (NSTE-ACS). These patients can be categorized on the basis of elevated cardiac biomarkers. Patients with elevated cardiac biomarkers in the appropriate clinical context are considered to have non-ST segment myocardial infarction (NSTEMI). ECG changes such as ST depression, transient ST elevation, and/or prominent T-wave inversions may be present but are

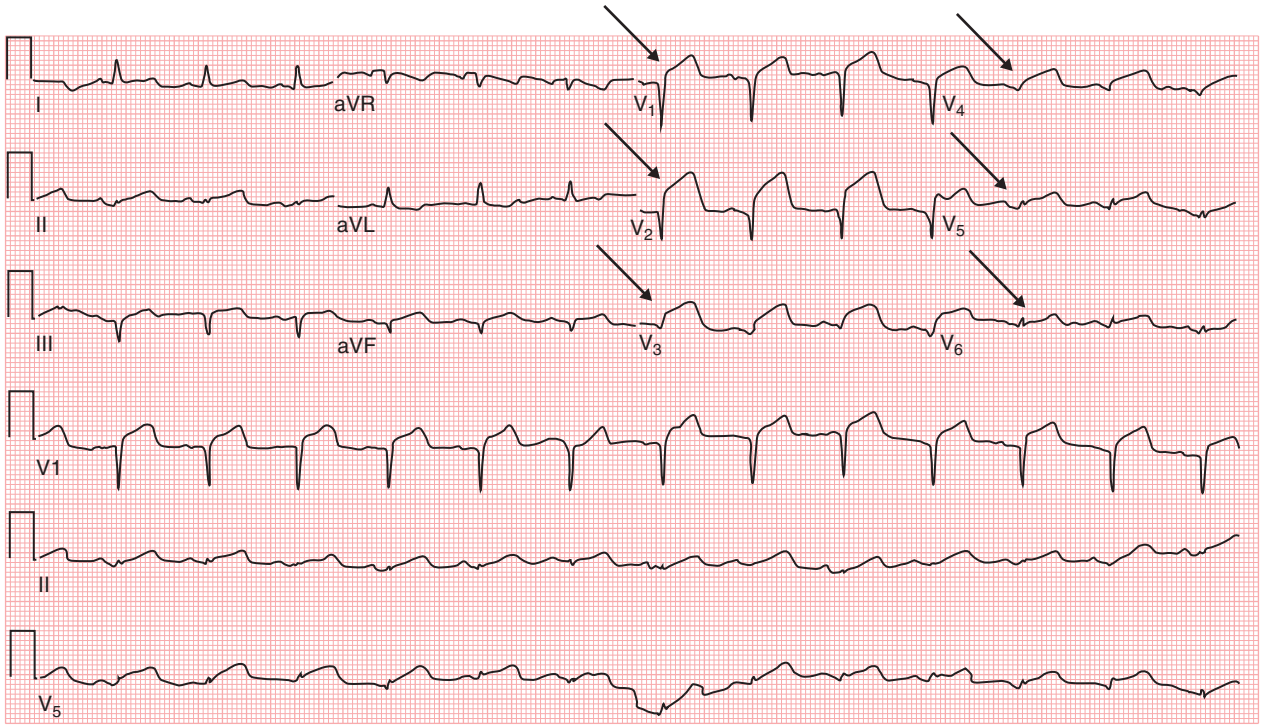


Figure 3.2 Anterior wall myocardial infarction, arrows pointing to ST elevations.

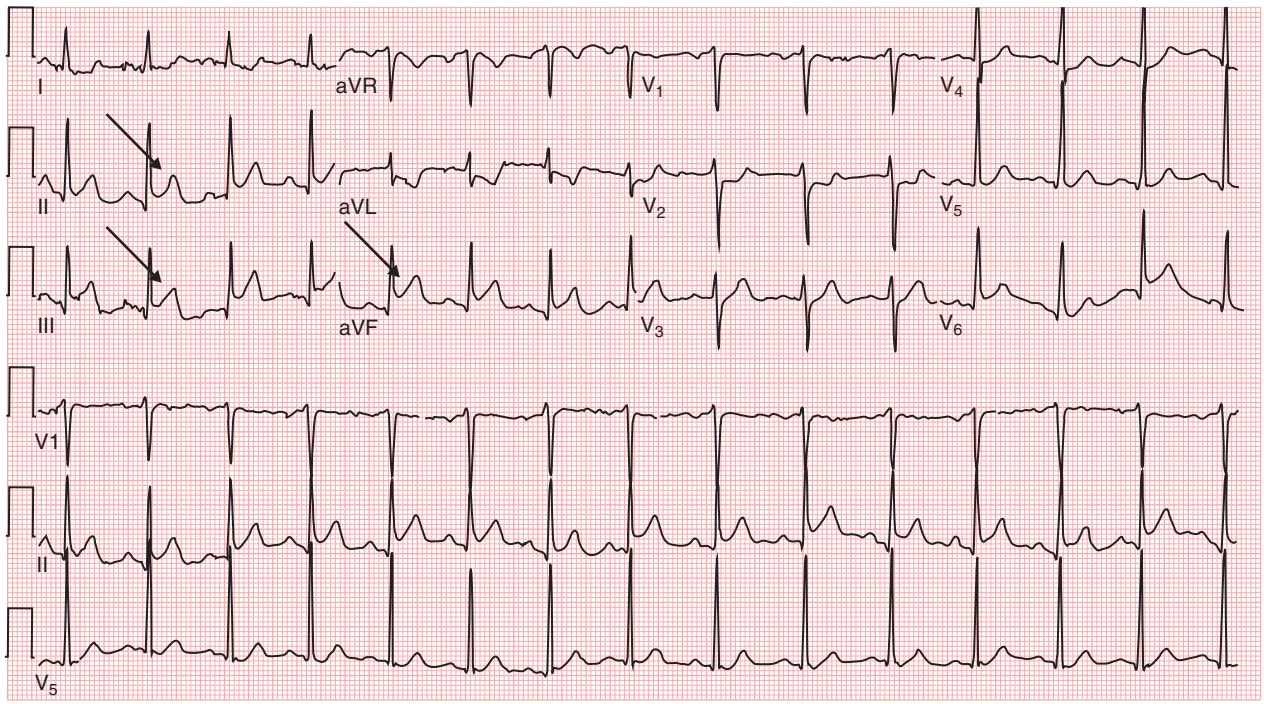


Figure 3.3 Inferior wall myocardial infarction, arrows pointing to ST elevations.

not required for a diagnosis of NSTEMI. Patients with clinical symptoms but with no elevations in cardiac biomarkers are considered to have unstable angina (UA)[25].

Currently, there is little data on the management of myocardial infarction and injury in the post-operative setting. In patients who fulfill the diagnostic criteria for an acute MI, immediate consultation with a cardiologist, cardiac catheterization laboratory, and surgical team should be done in order to facilitate immediate revascularization when possible. These patients should receive guideline-directed medical therapy (GDMT) according to the AHA Guideline for the Management of ST-Elevation Myocardial Infarction[26]. Patients who develop NSTE-ACS following noncardiac surgery should receive GDMT with limitations imposed by the specific surgical procedure and the severity of the NSTE-ACS[25].

Congestive Heart Failure

PREOPERATIVE

Heart failure is a diverse clinical syndrome due to any structural or functional impairment of left ventricular filling or ejection of blood[27]. Patients with heart failure can have a reduced left ventricular ejection fraction, <40%, (HFrEF), or a heart failure with preserved left ventricular ejection fraction, >50%, (HFpEF)[27]. Common symptoms include fatigue, orthopnea, shortness of breath either at rest or exertion, dyspnea, tachypnea, cough, lower extremity edema, increasing abdominal girth or discomfort, and loss of appetite. Prior to surgery, the presence of pulmonary or systemic congestion should be determined. Patients with pulmonary congestion may have rales, dullness to percussion, or diminished breath sounds. However typical lung exam findings may be absent in patients with elevated left ventricular filling pressures due to compensatory changes in lymphatic and perivascular tissue. The presence of increased jugular venous pressure (JVP) has a good sensitivity (70%) and specificity (79%) for estimating an increased left ventricular filling pressure[28]. Patients with decompensated CHF should be treated according to GDMT for heart failure[27]. A two-dimensional echocardiogram should be performed in patients who have newly diagnosed heart failure, develop a significant clinical change, or receive treatment that affects cardiac function.

POSTOPERATIVE

Patients with active or stable heart failure have an increased risk for perioperative morbidity and mortality[2,29]. The presence of a severely decreased, <30%, left ventricular ejection fraction, is an independent risk factor in perioperative outcome and increased long-term mortality in patients undergoing elevated-risk noncardiac surgery[30].

There is limited data on the use of pulmonary artery catheters perioperatively. The routine use of pulmonary artery catheters perioperatively is not recommended[2]. They may be considered in patients who are unable to have medical conditions that may affect hemodynamics corrected prior to surgery[2]. According to the 2013 ACCF/AHA Guideline for the Management of Heart Failure, pulmonary artery catheters should be used in those patients who have respiratory compromise or impaired perfusion that cannot be adequately assessed clinically (Class I)[27].

Valvular Heart Disease

PREOPERATIVE

Since the progression of VHD may be slow, patients may not exhibit symptoms due to a gradual decrease in their daily activities. A detailed examination may reveal signs of severe VHD. Echocardiography is recommended in patients with suspected moderate or greater degree of stenosis or regurgitation who have not had an echocardiogram within one year or who exhibit a change in their clinical status on examination[31]. In patients who meet the criteria for treatment of the valvular disease, intervention prior to elective surgery is indicated[31].

Patients who have severe AS should be evaluated for a change in their clinical symptoms. The Class I recommendations for aortic valve intervention include: 1) symptomatic patients; 2) asymptomatic patients with severe AS with a LVEF <50%; and, 3) patients with severe AS who are undergoing other cardiac surgery[31]. Options for treatment include surgical aortic valve replacement (SAVR), transcatheter aortic valve replacement (TAVR), and balloon valvuloplasty. Current indications for TAVR include patients who have a prohibitive surgical risk and a predicted post-TAVR survival of >12 months. Balloon aortic valvuloplasty may be considered as a bridge to SVAR or TAVR in those patients who require emergent or urgent surgery (Class IIb)[31].

Patients with severe mitral stenosis (MS) should also be evaluated prior to surgery. Class I indications for intervention include patients who are symptomatic. Patients with suitable anatomy can undergo a percutaneous mitral balloon commissurotomy.

Patients with chronic aortic insufficiency and chronic mitral insufficiency should be managed according to the Guidelines for Management of Patients with Valvular Heart Disease[31].

Patients with hypertrophic cardiomyopathy (HCM) have unexplained asymmetric pattern of hypertrophy associated with non-dilated ventricular chambers in the absence of a cardiac or systemic disorder that could explain the hypertrophy[32]. Based on echocardiography, HCM is defined by an end-diastolic wall thickness ≥ 1.5 cm in any myocardial segment accompanied by a normal wall thickness in the other segments. The complex pathophysiology of HCM includes: left-ventricular outflow tract (LVOT) obstruction, diastolic dysfunction, myocardial ischemia, autonomic dysfunction, mitral regurgitation, and atrial and ventricular arrhythmias. Patients may have an implantable cardiac defibrillator (ICD) if there is a history of cardiac arrest, ventricular fibrillation, or hemodynamically significant ventricular tachycardia[32]. There are no large trials examining perioperative risk. However, retrospective data suggests that patients with HCM have an increased operative risk. In one study with 227 patients with HCM, the presence of HCM tripled the risk of perioperative MI and death[33].

Except in highest risk patients, prophylactic antibiotics are not recommended for patients with VHD undergoing genitourinary (GU) procedures (Class III)[34]. Antibiotic therapy may be reasonable prior to elective cystoscopy or other urinary tract procedures in patients who are at highest risk for endocarditis with an enterococci urinary tract infection or colonization (Class IIb)[34]. Highest risk patients include: 1) prosthetic cardiac valve; 2) previous infective endocarditis; 3) congenital heart disease (CHD)- unrepaired cyanotic disease, completely repaired CHD with prosthetic material or device during the first six months, repaired CHD with residual defects; and, 4) cardiac transplantation recipients who develop cardiac valvulopathy. If they require urgent procedures, treatment with an antimicrobial effective against enterococci may also be reasonable (Class IIb)[34].

POSTOPERATIVE

Patients with AS have a fixed obstruction to forward blood flow. During anesthesia, a decrease in vascular resistance

results in hypotension due to an inability to increase cardiac output. This results in an ischemic cascade due to a decrease in coronary perfusion resulting in a further decline in cardiac output. Atrial arrhythmias in the setting of severe AS also lead to hypotension due to the loss of atrial contractility. Patients with severe symptomatic AS undergoing nonemergent procedures had a 2.1% 30-day mortality compared to 1% in patients without severe AS[35]. In addition, there is an increased frequency of postoperative MI. In emergent and urgent noncardiac surgery, patients with severe AS had a 5.9% mortality[36].

In patients with MS, tachycardia, either sinus tachycardia or atrial arrhythmias, should be avoided. A rapid ventricular rate will lead to a decrease in diastolic filling time leading to an increase in left atrial pressure, resulting in pulmonary edema. In addition, judicious use of intravenous fluids should be used perioperatively to avoid pulmonary edema.

Perioperatively, in patients with aortic or mitral insufficiency, adequate preload should be maintained and significantly elevated blood pressures should be avoided.

In patients with HCM, the effects of anesthesia, perioperative volume loss, arterial vasodilatation, and tachycardia may increase the degree of LVOT obstruction resulting in decreased cardiac output. In addition, increased contractility, such as the use of inotropic agents, will also increase the degree of LVOT obstruction. Maneuvers to improve hypotension include intravenous fluids and beta-blockers. Drugs that increase systemic vascular resistance without increasing heart rate or contractility, such as phenylephrine and vasopressin, can also be used[37]. Perioperative atrial fibrillation may also lead to hemodynamic compromise due to the loss of atrial kick. Pharmacologic or direct current cardioversion may be required.

Arrhythmias

PREOPERATIVE

Patients may have supraventricular or ventricular arrhythmias. Patients with unstable atrial or ventricular arrhythmias should be referred to a cardiologist prior to surgery.

Supraventricular tachycardias (SVT) are a group of arrhythmias with atrial and/or ventricular rates above 100 beats per minute (bpm) with a mechanism that occurs at or above the bundle of His[38]. This definition excludes atrial fibrillation. Patients with SVT may present with palpitations, panic or anxiety, neck pulsations, lightheadedness, or syncope. Patients may have hemodynamic instability due to the presence of a SVT regardless of the ventricular rate[39]. Patients may be managed medically or undergo catheter-based ablation.

Atrial fibrillation involves uncoordinated atrial activation resulting in an ineffective atrial contraction. ECG manifestations include: 1) irregular atrial activity, 2) absence of distinct P waves; and, 3) irregular R-R intervals[40]. Atrial fibrillation can be paroxysmal, persistent, or permanent. Paroxysmal atrial fibrillation terminates spontaneously or with intervention within seven days of onset. Episodes may occur with variable frequency. Persistent atrial fibrillation is continuous atrial fibrillation that is longer than seven days but less than 12 months. Permanent atrial fibrillation is characterized when the patient or physician has decided to defer further attempts to maintain sinus rhythm[40]. Patients may be treated with beta-blockers, non-dihydropyridine calcium channel blockers, or antiarrhythmic medications. In addition, patients should be treated with anti-thrombotic therapy in order to prevent thromboembolism. For patients with a CHA_2DS_2-Vasc score (congestive heart failure, hypertension, age ≥ 75 years [2 points], diabetes mellitus, prior stroke or TIA or thromboembolism [2 points], vascular disease, age 65 to 74 years, female sex), ≥1 oral anticoagulation is recommended[40]. Options for anticoagulation include aspirin, warfarin, and target-specific oral anticoagulants. These include a direct thrombin inhibitor, dabigatran, and direct factor Xa inhibitors, rivaroxaban, apixaban, and edoxaban. There is limited data on bridging with low molecular weight heparin (LMWH) or unfractionated heparin[40]. There is also limited data on the management of direct thrombin and factor Xa inhibitors perioperatively. The timing of cessation of and resumption of therapeutic coagulation should be guided by the individual risks and benefits.

Patients may have an SVT due to an accessory pathway. Wolff-Parkinson-White (WPW) syndrome is characterized by patients who have SVT and ventricular pre-excitation on ECG, short PR and delta wave (Fig. 3.4). Patients may also have an accessory pathway that is not evident on the 12-lead ECG (concealed accessory pathway)[38].

Patients with ventricular tachycardia (VT) should be evaluated by a cardiologist in order to determine whether the patient is stable and an appropriate surgical candidate.

POSTOPERATIVE

Patients who develop tachycardia postoperatively should have a 12-lead ECG. An ECG that reveals a wide complex tachycardia may either have VT or SVT with abnormal conduction. SVT with abnormal conduction may occur in the setting of existing bundle branch block or intraventricular conduction defect, aberrant conduction due to tachycardia, electrolyte and metabolic disorders, conduction over an accessory pathway, paced rhythm, or artifact[38]. It is important to differentiate SVT from VT since the administration of diltiazem or verapamil may result in hemodynamic instability in the setting of VT or atrial fibrillation with pre-excitation. Patients with pre-excitation who develop arrhythmias postoperatively should be managed in consultation with a cardiologist.

Class I recommendations for acute treatment of patients with SVT include vagal maneuvers, adenosine (Fig. 3.5), and synchronized cardioversion for hemodynamically unstable SVT or when pharmacologic therapy is contraindicated[38].

Patients who develop complex ventricular ectopy such as ventricular tachycardia should be evaluated for myocardial ischemia, electrolyte abnormalities, or adverse effects from medications.

Bradyarrhythmias postoperatively may be due to sleep apnea, electrolyte abnormalities, myocardial ischemia, medications, or due to increased vagal tone factors such as pain[2].

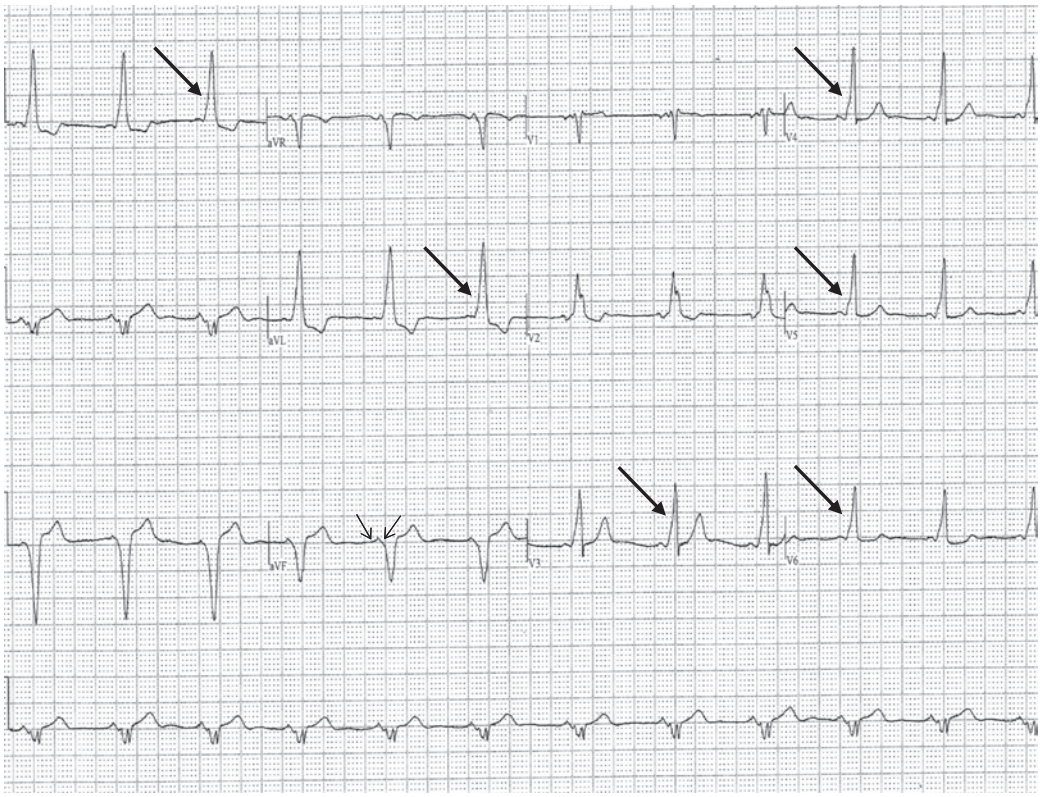


Figure 3.4 Pre-excitation in patient with WPW Syndrome, closed arrows=delta waves, Open arrows=short PR interval.

Cardiovascular Implantable Electronic Devices

PREOPERATIVE

There are a wide variety of CIEDs available. Communication between the CIED and surgical teams is required to develop an individualized treatment plan.

Device interaction is generally electrical interference from nonphysiologic electrical sources, such as electrocautery, or rarely direct damage to the generator or leads[41]. In patients undergoing monopolar surgery, inhibition of pacing and inappropriate activation of anti-tachycardia therapies may occur. Patients who have an inhibition of pacing may experience hemodynamic instability. In patients with ICDs, over-sensing results in inhibition of pacing and inappropriate ICD therapy. This includes both anti-tachycardic pacing therapy and ICD shocks. Uncommonly, electrical reset of the pulse generator, permanent damage or failure of the pulse generator, and damage to the lead-myocardial interface may occur[41].

Prior to surgery, the CIED team should be notified of the type of procedure, anatomic location, use of monopolar electrosurgery, other sources of electromagnetic interference (EMI), surgical venue, post-procedural recovery, and any unusual surgical circumstances. The CIED team will communicate the history of the device, pacemaker (PPM) dependency, and the appropriate perioperative CIED recommendations. Patients with pacemakers are recommended to have the device evaluated every 3 to 12 months, and patients with ICD and cardiac resynchronization therapy defibrillators (CRT-D) every 3 to 6 months either in person or by remote interrogation[42]. Patients who have had a change in their clinical condition should have their devices reevaluated prior to surgery. Devices near Elective Replacement Time may be unreliable and the generator should be changed prior to surgery.

In general, electrosurgery applied below the umbilicus is unlikely to cause pacemaker or ICD/CRT-D interference as compared to above the umbilicus. The greatest risk of over-sensing occurs when the anatomical surgical site and placement of the return electrode occurs across the CIED and/or leads[41]. In order to minimize the effects on the CIED, patients undergoing TURP should have placement of the return pads on the buttock or thigh. Patients who are pacemaker dependent, asynchronous pacing by programming or placement of a magnet over the pulse generator may be required for most procedures above the umbilicus. Inactivation of ICD detection is recommended for all procedures using monopolar electrosurgery above the umbilicus. Intraoperatively external defibrillation equipment should be available. It is important to note that application of a magnet over an ICD will not protect the patient from EMI inhibition of pacing. Changing the pacing mode will require reprogramming of the ICD. All patients should have plethysmographic or arterial pressure monitoring during the procedure since electrocautery may interfere with electrocardiographic monitoring and interpretation of the patient's underlying rhythm[41].

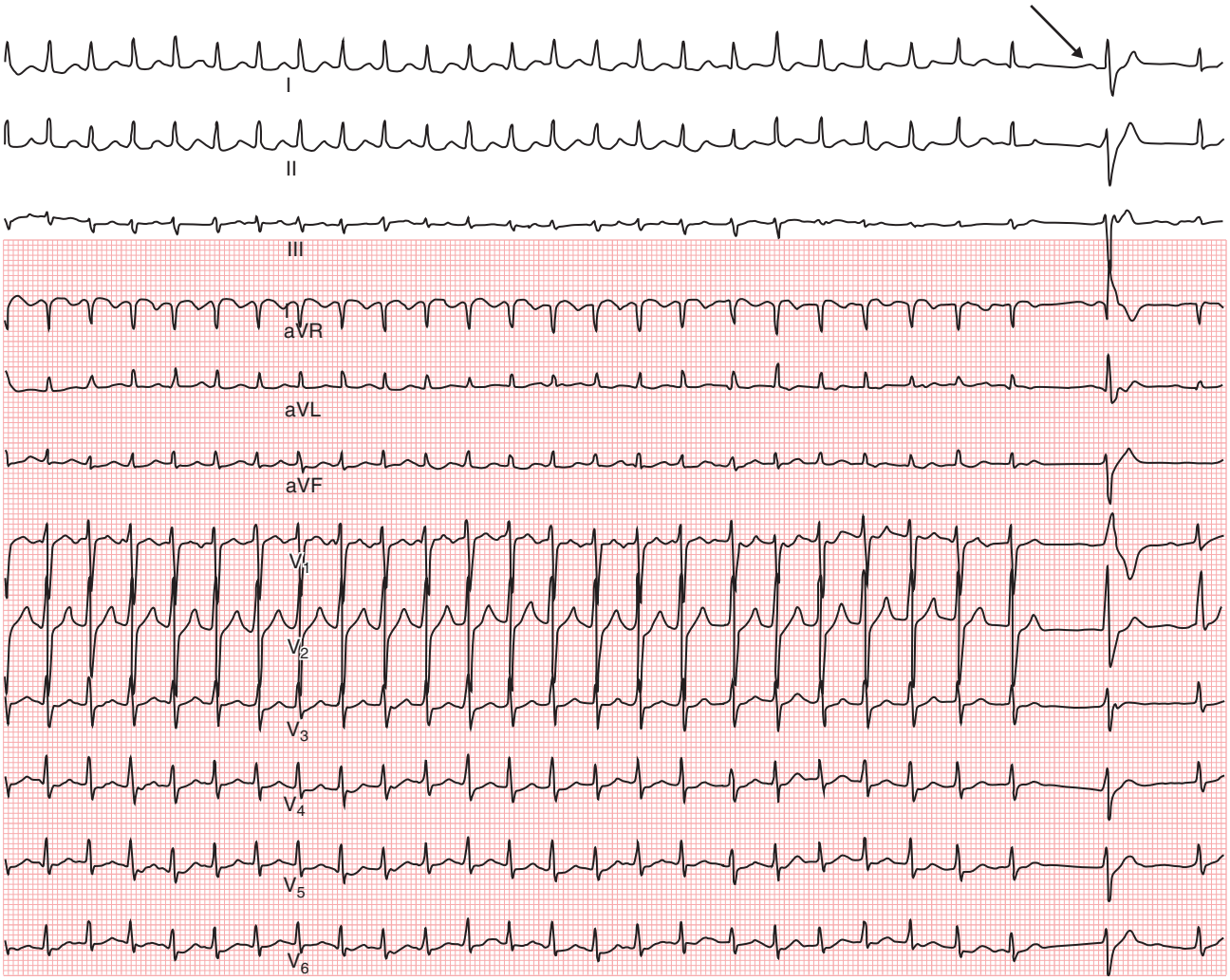


Figure 3.5 Narrow complex PSVT, arrow points to P wave and conversion to normal sinus rhythm after administration of adenosine.

POSTOPERATIVE

Postoperatively, patients with an ICD should have continuous cardiac monitoring until a member of the CIED team reevaluates the ICD and confirms that the appropriate preoperative settings are restored. This is essential since patients with ICDs are considered to be at risk for ventricular arrhythmias perioperatively[41]. Postoperative assessment of the PPM will depend on the operative environment. Patients who have intraoperative reprogramming, unexpected hemodynamic change, emergent surgery above the umbilicus, procedures that have a possibility of affecting device function, or who are unable to logistically have the device evaluated within one month should have the device evaluated prior to transfer from a cardiac telemetry environment[41]. Unless there was a change in the patient's clinical status perioperatively, patients undergoing transurethral resection of the prostate do not need additional CIED evaluation. Patients who require lithotripsy should have their device evaluated within 1 month unless there was a clinical change during the procedure[41]. Patients undergoing monopolar electrosurgery with no unexpected perioperative complications should have their device evaluated within the month either in person or by remote telemetry[41].

Pulmonary Hypertension

PREOPERATIVE

Pulmonary hypertension is defined by the presence of mean pulmonary artery pressure (mPAP) ≥25 mmHg assessed by right heart catheterization[43]. The classification of pulmonary hypertension is based on groups of patients with similar pathological findings, hemodynamic profiles, and management strategies. Patients can be classified as: group 1, pulmonary arterial hypertension (PAH), mPAP≥25 mm Hg with normal pulmonary artery occlusion pressure ≤15 mm Hg and pulmonary vascular resistance above 3 wood units in the absence of pulmonary parenchymal or thromboembolic disease; group 2, pulmonary hypertension due to left heart disease; group 3, pulmonary hypertension due to lung diseases and/or hypoxia; group 4, chronic thromboembolic pulmonary hypertension; and group 5, pulmonary hypertension with unclear or multifactorial mechanisms (Box 3.1)[44].

In observational studies, patients with PAH have an increased morbidity and mortality[2]. Risk factors include urgency of surgery, severity of pulmonary hypertension,

Box 3.1 Classification of Pulmonary Hypertension*

1. Pulmonary arterial hypertension
   - 1.1 Idiopathic PAH
   - 1.2 Heritable PAH
     - 1.2.1 BMPR2
     - 1.2.2 ALK-1, ENG, SMAD9, CAV1, KCNK3
     - 1.2.3 Unknown
   - 1.3 Drug and toxin induced
   - 1.4 Associated with:
     - 1.4.1 Connective tissue disease
     - 1.4.2 HIV infection
     - 1.4.3 Portal hypertension
     - 1.4.4 Congenital heart diseases
     - 1.4.5 Schistosomiasis
   - 1′. Pulmonary veno-occlusive disease and/or pulmonary capillary hemangiomatosis
   - 1″. Persistent PH of the newborn
2. PH due to left heart disease
   - 2.1 Left ventricular systolic dysfunction
   - 2.2 Left ventricular diastolic dysfunction
   - 2.3 Valvular disease
   - 2.4 Congenital/acquired left heart inflow/outflow tract obstruction and congenital cardiomyopathies
3. PH due to lung diseases and/or hypoxia
   - 3.1 Chronic obstructive pulmonary disease
   - 3.2 Interstitial lung disease
   - 3.3 Other pulmonary diseases with mixed restrictive and obstructive pattern
   - 3.4 Sleep-disordered breathing
   - 3.5 Alveolar hypoventilation disorders
   - 3.6 Chronic exposure to high altitude
   - 3.7 Developmental lung diseases
4. Chronic thromboembolic PH
5. PH with unclear multifactorial mechanisms
   - 5.1 Hematologic disorders: chronic hemolytic anemia, myeloproliferative disorders, splenectomy
   - 5.2 Systemic disorders: sarcoidosis, pulmonary histiocytosis, lymphangioleiomyomatosis
   - 5.3 Metabolic disorders: glycogen storage disease, Gaucher disease, thyroid disorders
   - 5.4 Others: tumoral obstruction, fibrosing mediastinitis, chronic renal failure, segmental PH

BMPR 2, bone morphogenetic protein receptor type 2; CAV1, caveolin-1; ENG, endoglin; HIV, human immunodeficiency virus; PAH, pulmonary arterial hypertension; PH, pulmonary hypertension

*5th World Symposium on Pulmonary Hypertension, Nice, France, February 27 to March 1, 2013

(Adapted from Simonneau G, Gatzoulis MA, Adatia et al. Updated clinical classification of pulmonary hypertension. J Am Coll Cardiol. 2013; 62 (Suppl 25): D34-D41.)

degree of RV dysfunction, and surgery in a center without expertise in pulmonary hypertension[2]. Given the complex nature of PAH, patients should be managed at a PAH center of excellence[45]. Preoperatively, patients should have a thorough cardiac evaluation and optimization prior to surgery. Signs and symptoms of deterioration may include changes in functional status, presence of elevated jugular venous pressure, congestive heart failure, hypoxia, or syncope. In addition, the patient's pulmonary hypertension medications and the possibility of additional pulmonary hypertension specific medications should be made available prior to surgery[46].

POSTOPERATIVE

Postoperative management requires close coordination between the surgeon and PAH team. Postoperative complications may include respiratory failure, cardiac arrhythmias, congestive heart failure, renal insufficiency, sepsis, hepatic dysfunction, hypertension, cardiac ischemia and stroke[46].

Perioperative Medical Interventions

Several classes of drugs including beta blockers, statin therapy, alpha agonists, angiotensin-converting enzyme (ACE) inhibitors, and antiplatelet therapy have been studied perioperatively. In addition, the use of anticoagulants is also discussed briefly.

Studies have shown that perioperative beta blockers can reduce perioperative cardiac events but were associated with an increased risk of stroke, hypotension and bradycardia[2,47,48]. Given this, it is not recommended to start beta-blocker therapy on the day of surgery (Class III)[2]. The current guidelines recommend continuing beta-blockade for patients who are on beta-blockers chronically (Class I). Beta-blockers can be started on those patients who have 3 or more risk factors, such diabetes, renal insufficiency, cerebrovascular accident, heart failure, coronary artery disease, and in patients who are at intermediate-or high-risk for myocardial ischemia (Class IIb)[2]. The beta-blocker should be started 2 to 7 days prior to surgery.

Patients on chronic statin therapy should have them continued perioperatively (Class I)[2]. Alpha-2 agonists, such as clonidine, are not recommended in patients undergoing noncardiac surgery[2,49]. ACE inhibitors may be continued perioperatively, and if they are held prior to surgery, they should be restarted when the patient is stable[2].

The benefits of aspirin in non-stented patients undergoing surgery is uncertain. In patients with cerebrovascular disease or increased risk of CAD with no history of coronary stenting, it may be reasonable to continue daily aspirin therapy, where the benefits of decreasing potential cardiovascular events outweigh the risks of perioperative bleeding (Class IIb)[2]. Given data that suggests that aspirin was associated with a higher risk of bleeding and did not reduce the risk of myocardial infarction, the initiation or continuation of aspirin is not recommended in patients undergoing elective noncardiac noncarotid surgery unless the risk of ischemic events outweighs the risks of surgical bleeding (Class III)[2,50].

For patients with mechanical mitral valve or mechanical aortic valve with one additional risk factor such as atrial fibrillation, prior thromboembolism, left ventricular dysfunction, older-generation prosthetic aortic valve, or hypercoagulable state, bridging anticoagulation may be appropriate when the risk of surgical bleeding is more than minimal (Class I)[31]. In patients with mechanical valves undergoing minor procedures, continuation of

therapeutic anticoagulation is recommended (Class I)[31]. Patients with mechanical aortic valves and no other risk factors for thrombosis, temporary cessation of vitamin K antagonists without bridging can be done as long as the interruption is brief (Class I)[31]. Factor Xa inhibitors and direct thrombin inhibitors are not indicated for mechanical valves.

In patients with atrial fibrillation, the 2014 AHA/ACC/HRS Guideline for the Management of Patients with Atrial Fibrillation does not provide specific perioperative recommendations but recommends an individualized approach[40].

No guidelines are available for factor Xa inhibitors and direct thrombin inhibitors perioperatively. In patients with normal renal function undergoing elective procedures, it is suggested to discontinue the anticoagulant ≥ 48 hours[2]. In patients on dabigatran requiring urgent reversal, idarucizumab is now available to completely reverse the anticoagulant effects[51]. For patients on vitamin K antagonists, options include fresh frozen plasma, prothrombin complex concentrates, and vitamin K. Vitamin K is not routinely recommended due to the delay in both action and return to a target therapeutic level. As of this writing, there are no approved reversal agents for factor Xa inhibitors.

References

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Chapter 3 Questions

1. An 85-year-old male with a past medical history significant for diabetes mellitus, COPD, osteoarthritis, hypertension, and hyperlipidemia is scheduled for a radical nephrectomy. He is unable to walk more than a 1/2 block due to dyspnea. He is referred for further cardiac evaluation. The next appropriate step is:
   a. Schedule the patient for surgery
   b. Refer for cardiac catheterization
   c. Schedule pharmacologic stress test
   d. Start beta blocker on day of surgery and proceed with surgery
   e. Pulmonary consultation

2. 70-year-old female with no prior history and an excellent exercise tolerance develops chest pain postoperatively after a laparoscopic partial nephrectomy. Her ECG prior to surgery was normal. On your arrival to the recovery room, the patient develops chest pain and then ventricular tachycardia. The most likely diagnosis is:
   a. Atypical chest pain due to endotracheal intubation
   b. Pulmonary embolism
   c. Acute myocardial infarction
   d. Pneumothorax
   e. Incisional pain

3. An 80-year-old male with a past medical history significant for diabetes mellitus, hypertension, and hyperlipidemia is referred for cardiac evaluation. He reports exertional dyspnea which began six months ago. He denies any chest pressure or syncope. On examination, his blood pressure is 110/80 mm Hg with the resting pulse 95 bpm. He has a 3/6 systolic crescendo murmur best heard at the base and radiates to the carotid arteries. The next appropriate diagnostic test is:
   a. An echocardiogram to evaluate for mitral regurgitation
   b. An echocardiogram to evaluate for hypertrophic cardiomyopathy
   c. No further testing is warranted
   d. An echocardiogram to evaluate for aortic stenosis
   e. Exercise stress test to assess functional capacity

4. 77-year-old female with a past medical history significant for hypertension, diabetes mellitus and peripheral arterial disease develops atrial fibrillation in the recovery room. Her blood pressure is 120/70 mm Hg with a pulse of 80 bpm. She has no evidence of JVD. Heart exam is significant for an irregularly irregular pulse with a 3/6 systolic murmur at the apex. The appropriate intervention is:
   a. Start intravenous beta blocker
   b. Check CBC, electrolytes and TSH
   c. Start an intravenous diltiazem drip
   d. Emergent electrical cardioversion
   e. Intravenous amiodarone

5. The same patient remains in atrial fibrillation with ventricular rates in the 70s. Her echocardiogram shows a normal left ventricle ejection fraction with mitral valve prolapse and severe mitral regurgitation. She has been stable with no signs of surgical bleeding. Her renal function is normal. She is now ready for discharge. The next appropriate step is:
   a. Start aspirin
   b. Start therapeutic enoxaparin and transition to warfarin
   c. Start dabigatran
   d. Start rivaroxaban
   e. Start apixaban

6. You are called to the bedside for a patient who has increasing hypotension postoperatively. The patient has a history of hypertrophic cardiomyopathy with an ICD. Prior to your arrival the patient was started on intravenous dobutamine. The patient then developed atrial fibrillation. His blood pressure is 80/60 mm Hg and telemetry shows atrial fibrillation with ventricular rate of 120. His 02% is 90%. Appropriate interventions include all the following except:
   a. Emergent cardioversion
   b. 1L bolus of normal saline
   c. Increase the dosage of dobutamine
   d. Intravenous beta blockers
   e. Pain control

7. An 80-year-old man was admitted for urgent surgery. Patient reports a recent episode of syncope and increasing chest pain. An echocardiogram shows a normal left ventricular ejection fraction and severe aortic stenosis with an aortic valve area of 0.7 cm^2. Prior to surgery, you would recommend:
   a. No intervention and can proceed with surgery
   b. Surgical aortic valve replacement
   c. Transcatheter aortic valve replacement
   d. Balloon aortic valvuloplasty
   e. CT scan of the aorta to evaluate for aortic dissection

8. A 70-year-old female underwent drug eluting stent to her left anterior descending artery for unstable angina 8 months ago. Post-procedure, she developed hematuria and was found to have renal cancer. Her current medications include aspirin and clopidogrel. Appropriate perioperative recommendations include:
   a. Schedule surgery for next week
   b. Delay surgery for six weeks, stop clopidogrel two weeks prior to surgery and continue an aspirin
   c. Delay surgery for six months and discontinue both aspirin and clopidogrel
   d. Stop clopidogrel five days before surgery,continue an aspirin, and proceed with surgery
   e. Change clopidogrel to prasugrel

9. A 60-year-old male with a past medical history significant for a nonischemic cardiomyopathy with ejection fraction of 25%, hypertension, diabetes mellitus, and an ICD is scheduled for surgery. He has a good exercise tolerance with no recent chest pain or shortness of breath. His last ICD interrogation was two months ago and showed no events. His physical exam is significant for blood pressure 120/70 mm Hg, resting pulse of

60 bpm. He has no JVD. His lungs were clear to auscultation. He had a 2/6 holosystolic murmur at the apex. He had no lower extremity edema. His medications include carvedilol, lisinopril, furosemide, spironolactone, and an aspirin. Appropriate recommendations include:
   a. Refer patient for evaluation of coronary ischemia
   b. Proceed with surgery with recommendations from his electrophysiologist
   c. Schedule cardiac catheterization
   d. Increase diuretics
   e. Repeat echocardiogram

10. The same patient on the day of surgery reports having a syncopal episode two days prior to surgery. He denied any chest pain, shortness of breath, palpitations. Appropriate recommendations include:
   a. Proceed with surgery
   b. Cancel patient and refer for outpatient evaluation with his electrophysiologist
   c. Send to emergency room for evaluation with his electrophysiologist
   d. Send to emergency room for evaluation for cardiac catheterization
   e. Reschedule the surgery for the following week

Answers

1. **c.** Given his symptoms and we are unable to assess his exercise tolerance, he should have a pharmacologic stress test prior to surgery due to his risk factors and symptoms.
2. **c.** Given the presence of chest pain and ventricular tachycardia, this is suggestive of an acute myocardial infarction.
3. **d.** The physical exam suggests aortic stenosis and in the presence of symptoms and a significant murmur an echocardiogram is indicated.
4. **b.** Given the patient is hemodynamically stable, a work-up to evaluate a reversible cause is appropriate at this time.
5. **b.** Given her CHA2DS2-Vasc=6 (1 for hypertension, 2 for age>75, 1 for diabetes, 1 for female, and 1 for peripheral arterial disease), she should have therapeutic anticoagulation. Since she has severe valvular disease, she is not a candidate for dabigatran, rivaroxaban, or apixaban.
6. **c.** The patient has hypertrophic cardiomyopathy and increasing inotropic support will result in further outflow obstruction resulting in hypotension.
7. **d.** Given the patient needs urgent surgery, a balloon aortic valvuloplasty is an appropriate bridge to surgery.
8. **d.** The patient had revascularization more than six months ago. Given her need for surgery, it is reasonable to proceed with surgery while on an aspirin. Her clopidogrel should be stopped five days prior to surgery.
9. **b.** While the patient has a severely reduced ejection fraction, he does not have any signs of decompensated congestive heart failure or recent ICD events. Therefore, a repeat echocardiogram is not indicated. He should have appropriate recommendations for the management of his ICD perioperatively.
10. **c.** Given the patient had a syncopal event, he should be referred to the emergency room for further cardiac evaluation of his ICD. He does not have any symptoms of acute coronary ischemia.

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4 Preoperative Hematologic Assessment and Management of Hematologic Complications

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CHAPTER OUTLINE

Preoperative Evaluation
Abnormalities of Blood Components
Red Blood Cells
Platelets
von Willebrand's Disease
Hemophilia A and B
Rare Inherited Factor Deficiencies
Disorders of Increased Bleeding
Renal Failure
Disseminated Intravascular Coagulation
Primary Fibrinolysis
Vitamin K–related Disorders
Massive Transfusion Syndrome
Anticoagulated Patient
Antiplatelet Therapy
Anticoagulation Therapy
Management of Intraoperative Bleeding
Problems of Increased Coagulation
Hypercoagulable State
Physiology
Evaluating the Hypercoagulable Patient
Management
Deep Venous Thrombosis and Pulmonary Embolism
Management
Conclusion
Chapter 4 Questions and Answers

KEY POINTS

1. Although routine preoperative coagulation defect screening is not shown to be cost-effective, it is commonly used in patients at risk of significant bleeding during a planned procedure.
2. Anemia can affect surgical outcomes and should be corrected whenever possible before elective surgical procedures.
3. Urologists must become familiar with the ever-expanding number of anticoagulation medications for the safe perioperative management of their patients.
4. Individuals undergoing elective surgical procedures should discontinue the use of aspirin, clopidogrel, or nonsteroidal antiinflammatory drugs (NSAIDs) a full 7 to 10 days preoperatively to allow normalization of platelet function.
5. In patients with drug-eluting coronary stents, or specific indications for anticoagulation, the risk of stopping anticoagulation should be weighed against the risk of intraoperative bleeding, depending on the planned procedure.
6. Patients with abnormal preoperative partial thromboplastin time (PTT) value and no history of anticoagulation should undergo careful evaluation for clotting factor deficiency.
7. In patients with certain risk factors for a hypercoagulable state, and in patients at risk for venous thrombosis, evaluation for factor deficiency or lupus anticoagulant is indicated.
8. The risk factors for venous thrombosis can be thought of in the context of Virchow's triad for the pathophysiology of thrombus formation (stasis, hypercoagulability, and intimal injury).
9. Venous thromboembolism (VTE) prophylaxis recommendations should be risk adjusted.

Preoperative Evaluation

When evaluating patients for potential hematologic complications before any urologic surgical procedure, the most important first steps are thorough history taking and physical examination. The clinician taking the patient's history should pay specific attention to the following: any personal or family history of known bleeding disorder; a history of prolonged bleeding after trauma, surgery, or dental procedure; a history of liver disease, malabsorption, or malnutrition; and recent use of anticoagulants. Physical findings suggestive of coagulopathy include petechiae, ecchymosis, hematomas, purpura, and the stigmata of acquired disease, such as liver failure or uremia.

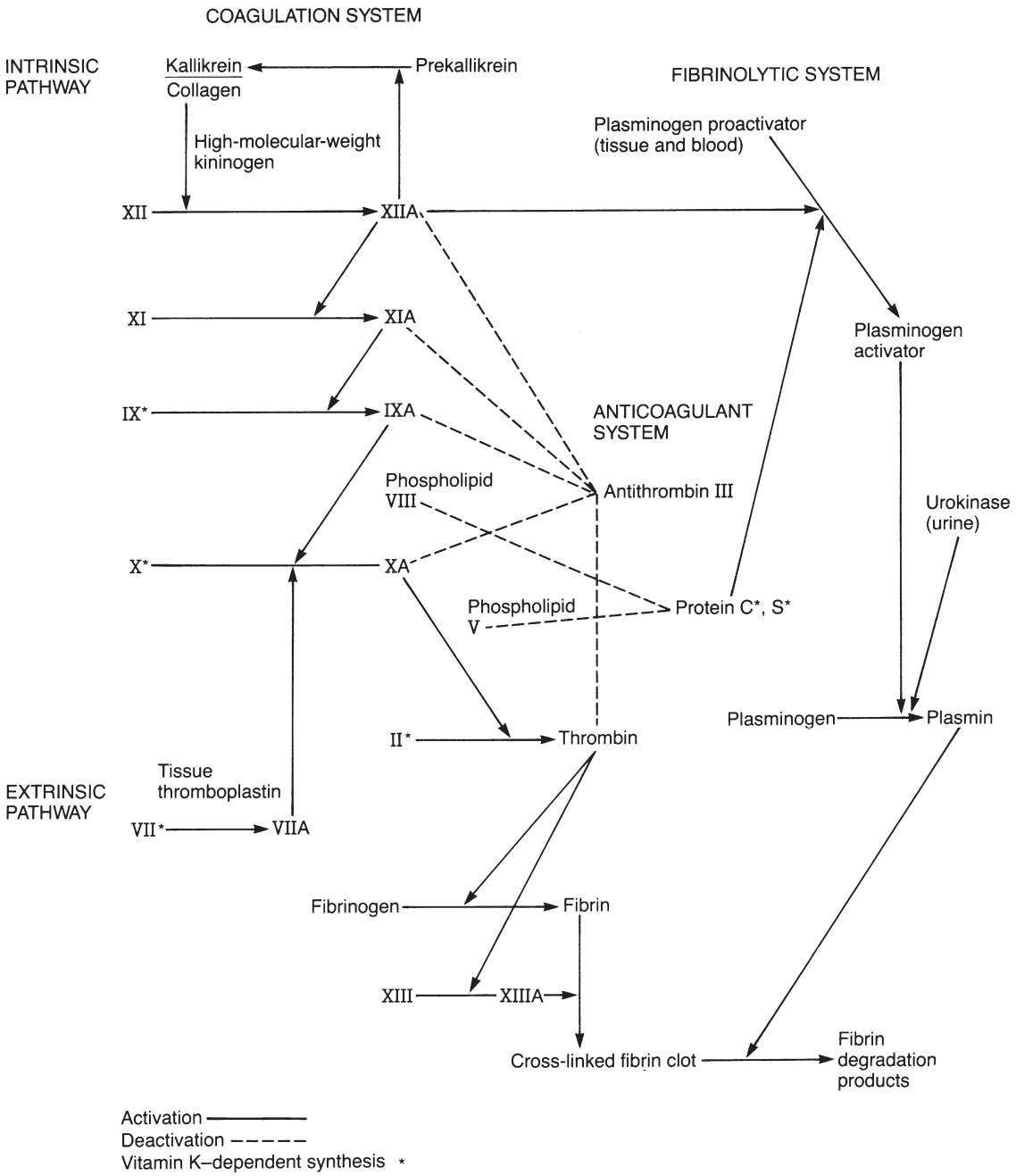


Figure 4.1 Normal clotting cascade.

Bleeding symptoms in the patient or in a member of the patient's family should prompt a laboratory evaluation. In addition, routine laboratory screening tests are often performed in asymptomatic patients, including complete blood count, platelet count, prothrombin time (PT), and activated partial thromboplastin time (aPTT). The PT measures the activity of the extrinsic clotting system, and the aPTT measures the intrinsic clotting system (Fig. 4.1). Measurement of the bleeding time is used to identify patients with possible platelet dysfunction. Further laboratory evaluation is unnecessary unless history, physical examination, or routine laboratory tests reveal an abnormality.

In obtaining preoperative screening PT, aPTT, and platelet count, surgeons attempt to identify asymptomatic patients at increased risk for intraoperative or postoperative hemorrhage. The evaluation of symptomatic patients is not considered screening. Most patients experiencing significant perioperative bleeding, however, would not be identified by preoperative screening measures because most bleeding episodes are the result of surgical technique rather

than of intrinsic coagulopathy. The risk of preexisting coagulopathy, in the absence of historical symptoms and signs of bleeding, is extremely low.

Multiple studies have evaluated the cost-effectiveness of baseline preoperative screening and, collectively, these studies recommended that preoperative screening for coagulopathy is unnecessary and should not be performed in the absence of clinical findings suggestive of an increased bleeding risk.[1–5] Preoperative testing should always be performed in all patients in whom adequate clinical assessment is not possible. The elimination of routine screening based on these criteria would reduce the total number of preoperative tests of coagulation by approximately 50%.[2] The limitations of coagulation testing are well known. Coagulation tests have been shown to have limited sensitivity and positive predictive value for bleeding episodes. Abnormal values may have little clinical significance or represent false positives and do not correlate with volume of blood loss or need for transfusion.[5]

These data do not support the use of routine preoperative screening coagulation tests in asymptomatic patients,[2–5] but despite these recommendations physicians continue to obtain routine PT, aPTT, and platelet count on all patients undergoing major extirpative or reconstructive procedures in which significant blood loss is possible.

Table 4.1 Complications of Transfusions per Unit Transfused

Complications	Frequency
REACTION	
Febrile nonhemolytic	1-4/100
Allergic	1-4/100
Delayed hemolysis	1/1000
Transfusion-related acute lung injury	1/5000
Acute hemolysis	1/12,000
Fatal hemolytic	1/100,000
Anaphylaxis	1/150,000
Alloimmunization (RBC)	1/100
Alloimmunization (HLA)	1/10
INFECTION	
Hepatitis B	1/220,000
Hepatitis C	1/1,800,000
HIV-1, -2	1/2,300,000
HTLV-1, -2	1/2,993,000
Malaria	1/4,000,000
RARE	
Allosensitization (RBC)	1/100
Allosensitization (HLA)	1/10
Graft-versus-host disease	Rare

HIV, human immunodeficiency virus; HLA, human leukocyte antigen; RBC, red blood cell; HTLV, human T lymphotropic virus

(Adapted from Dzieczkowski JS, Anderson KC. Chapter 113. Transfusion biology and therapy. In: Longo DL, Fauci AS, Kasper DL, Hauser SL, Jameson JL, Loscalzo J, editors. Harrison's Principles of Internal Medicine, 18e [Internet]. New York, NY: The McGraw-Hill Companies; 2012. Available from: http://mhmedical.com/content.aspx?aid=9119034.)

Abnormalities of Blood Components

RED BLOOD CELLS

Anemia detected in routine preoperative screening should be evaluated with regard to its functional significance and origin. Typically, a preferred preoperative hemoglobin level is >10 g/dL. Although lower intraoperative hemoglobin levels can generally be tolerated by most patients, these values are associated with an increased risk of morbidity and mortality. Additionally, anemia may reflect a previously unsuspected coexisting disease process that could have a significant effect on the perioperative course. Because anemia can be a primary disorder or can occur secondary to other systemic processes, a careful history and physical examination are essential and can provide extensive information about the underlying cause.[6]

Initial diagnostic studies should include reticulocyte count, mean corpuscular volume (MCV), examination of the peripheral blood smear, and a fecal occult blood test.[6] Many urologic conditions can be associated with anemia, including malignancy and chronic renal failure. Iron deficiency anemia has been associated with states of renal cell carcinoma. Direct involvement of the bone marrow by cancer may result in myelofibrosis and subsequent anemia, most often seen in metastatic prostate cancer.[7] Radiation therapy can lead to bone marrow suppression or vitamin B_{12} deficiency secondary to radiation ileitis.[8] The use of gastrointestinal segments in the urinary tract is associated with known metabolic derangements including vitamin B_{12} deficiency with utilization of the ileum. The body has about 3 years of vitamin B_{12} stores, after which the patient can develop megaloblastic anemia.[9] Many chemotherapeutic agents can cause myelosuppression. Commonly used antibiotics in urology, such as nitrofurantoin, sulfa compounds, and quinolones, can produce hemolytic anemia in patients with glucose-6-phosphate dehydrogenase deficiency. Hemolytic anemia has also been reported in association with renal cell carcinoma and seminoma.[10,11] Finally, hematuria itself can cause anemia if it is chronic or severe.

Understanding the cause of the anemia can dictate the appropriate perioperative course of action to minimize operative morbidity. For patients with an uncorrectable underlying cause of anemia who are judged to be at risk for functional compromise, therapy consists of transfusion. In patients who are undergoing surgical procedures that are deemed elective, it is advisable to proceed after correcting the underlying cause of anemia preoperatively and thereby avoiding transfusion. Preoperative transfusions should ideally be performed 24 hours in advance to allow regeneration of 2,3-diphosphoglycerate, which shifts the oxygen dissociation curve to increase oxygen availability to the tissues. Transfusions incur a potential risk of morbidity, including hemolytic reactions, allergic reactions, and transmission of viral diseases (Table 4.1).[12]

Erythrocytosis, a hematocrit level significantly higher than normal, increases blood viscosity and decreases oxygen transport. Erythrocytosis can significantly increase surgical morbidity and mortality, particularly related to thromboembolic complications. This increase in red blood cell (RBC) mass can be primary, as in polycythemia vera, or secondary. Common causes of secondary erythrocytosis are hypoxic states or paraneoplastic syndromes (as seen in

renal cell carcinoma and Wilms' tumor) likely resulting in increased production of erythropoietin. Patients with polycythemia vera should undergo preoperative phlebotomy to lower hematocrit levels to <45% to reduce the risk of thromboembolic complications. In patients with secondary erythrocytosis, the hematocrit should be lowered to <50%.[13,14]

PLATELETS

Normal platelet count can vary greatly among healthy individuals; a platelet count >50,000 is usually adequate for surgical hemostasis. Thrombocytopenia results from decreased production of platelets (radiation, primary marrow disorders, alcohol, drugs), increased peripheral destruction (autoimmune disease, disseminated intravascular coagulation [DIC], sepsis, drugs), sequestration (splenomegaly), or extracorporeal platelet loss (exsanguination). Initial therapy should consist of treating the underlying cause; if this is not possible then the next step is platelet transfusion. One unit of platelets can be expected to raise the platelet count by 5000 to 10,000/mm^3.

Thrombocytosis can be caused by myeloproliferative disorders and is associated with increased risk of both thrombotic and bleeding complications. Secondary or reactive thrombocytosis leads to an elevation of total number of platelets with normal function caused by underlying inflammation or infection. Patients with reactive thrombocytosis are not at increased risk of thrombotic events and do not require anticoagulation.[15]

Inherited defects of platelet function are rare genetic disorders that result in altered platelet function or morphology, most commonly involving deficiency of glycoprotein mediators that regulate aggregation or adhesions of platelets. Treatment or prevention of bleeding frequently requires platelet transfusion.[16]

Acquired intrinsic platelet dysfunction is most commonly due to medications that affect platelet function, but can also be caused by liver disease, uremia, hypothyroidism, and cardiopulmonary bypass. For acquired defects not related to medication, treatment is directed at the underlying cause.

VON WILLEBRAND'S DISEASE

von Willebrand's disease (vWD) is the most common inherited bleeding disorder and is a result of dysfunction or deficiency of von Willebrand Factor. vWD is a plasma protein that mediates platelet adhesion and binds to and stabilizes coagulation factor VIII in the circulation. The disease is transmitted in both an autosomal dominant and recessive fashion and affects both men and women. Symptoms are primarily related to platelet dysfunction and are usually manifested in late childhood. Symptoms most commonly include easy bruising and bleeding at skin sites or mucus membranes. Although spontaneous bleeding may be mild, serious gastrointestinal bleeding can occur. Treatment is preferably with cryoprecipitate and desmopressin (DDAVP), which induces endothelial release of vWD and coagulation factor VIII. Desmopressin can result in hyponatremia; very young or elderly patients are at highest risk for this side effect.[17]

HEMOPHILIA A AND B

Hemophilia A (factor VIII deficiency) and hemophilia B (factor IX deficiency) are extremely rare inherited disorders. Both deficiencies are typically inherited as a recessive X-linked trait and affect males almost exclusively. The underlying pathophysiology behind both diseases is based on the insufficient generation of thrombin by the factor VIIIa/IXa complex.

Hemophilia A occurs in 1 in 5000–7000 male births.[18,19] The aPTT is prolonged, whereas PT, fibrinogen level, and platelet count are normal. In severe deficiency, spontaneous bleeding may occur, whereas patients with moderate disease may only have excessive traumatic bleeding. The diagnosis is established by demonstrating a reduction in factor VIII activity. Patients with minor bleeding can generally be treated with factor levels that are 25–30% of normal; surgical patients generally require target levels that reach 75–100% of normal activity. Many different factor VIII preparations can be given; the half-life of factor VIII is 8 to 12 hours, and many administrations may be required to maintain a steady state. Most patients require 2 to 3 weeks of postoperative hematologic support to allow sufficient wound healing and scar formation.[16]

Hemophilia B, also known as Christmas disease, clinically resembles hemophilia A, but is less common with an incidence of 1 in 30,000 male births.[18,19] Replacement therapy with factor IX, as in hemophilia A, is recommended.

RARE INHERITED FACTOR DEFICIENCIES

Other factor deficiencies are much less common, and not all are associated with coagulopathies. The presentation and management of these disorders are outlined in Table 4.2. In general, these patients may present with ecchymosis, hematoma, or delayed traumatic bleeding.

Prothrombin deficiency is a very rare autosomal recessive disorder manifested by prolonged PT and variably prolonged aPTT. Prothrombin is usually converted to its active form thrombin (coagulation factor II) leading to fibrin formation. Maintenance of >15% of normal levels should be adequate for surgery and can be achieved with fresh frozen plasma (FFP).

Factor V deficiency, also called parahemophilia, is also a very rare disorder in which the PT and aPTT are prolonged. Approximately 25% of normal activity can be maintained for surgery by treatment with FFP.

Factor VII deficiency is uncommon and is inherited as an autosomal gene with intermediate penetrance. The PT is prolonged and the aPTT is normal. Replacement is achieved by transfusing plasma or factor VII replacement.

Inherited factor X deficiency is autosomal recessive. Maintenance of levels >40% of normal may be achieved with plasma transfusion in preparation for surgery.

Factor XI deficiency is an uncommon disorder inherited in an autosomal dominant fashion. A higher frequency of this deficiency is noted in the Ashkenazi Jewish population. These patients may not have bleeding histories but often present with epistaxis. Severe bleeding may occur with trauma or major surgery. Patients can successfully undergo urologic surgical procedures with adequate FFP therapy.

Table 4.2 Laboratory Findings and Treatment of Factor Deficiencies

Deficient Factor	PT	aPTT	TT	Bleeding Time	Replacement Factor
I	↑	↑	↑	↑, N	FFP, cryoprecipitate
II	↑	↑	N	N	FFP, factor IX concentrate
III*					
IV*					
V	↑	↑	N	N	FFP
VII	↑	N	N	N	FFP, factor IX concentrate
VIII	N	↑	N	N	cryoprecipitate, factor VIII concentrate
IX	N	↑	N	N	FFP, factor IX concentrate
X	↑	↑	N	N	FFP, factor IX concentrate
XI	N	↑	N	N	FFP
XII	N	↑	N	N	
XIII	N	N	N	N	FFP
vWF	N	↑	N	↑	FFP, cryoprecipitate

aPTT, activated partial thromboplastin time; FFP, fresh frozen plasma; N, normal time; PT, prothrombin time; TT, thrombin time; vWF, von Willebrand's factor; ↑, prolongation

*Deficiency affecting coagulation is unknown

(Adapted from Wilner ML, Rosove MH. Hematologic complications. In: Smith RB, Ehrlich RE, editors. Complications of Urologic Surgery: Prevention and Management. 2nd ed. Philadelphia: WB Saunders; 1990:441-52.)

Factor XII deficiency is not usually associated with bleeding manifestations, although the aPTT is prolonged. Therapy is not needed for this deficiency. Factor XII stabilizes fibrin into a covalent network, and in factor XII deficiency coagulation studies are normal except fibrin stability. Abnormal clot solubility and specific factor XII assay establish the diagnosis, and transfusion of FFP is sufficient for hemostasis.

Fibrinogen deficiency, or dysfibrinogenemia, is uncommon, and FFP or cryoprecipitate may be given to maintain a level of fibrinogen adequate for normal hemostasis.[20]

Disorders of Increased Bleeding

Coagulation and bleeding abnormalities are among the major problems encountered in the surgical or critically ill patient. Although most of these patients have no intrinsic abnormalities of hemostasis, either their underlying disease or the therapy of the disease may produce clinically significant bleeding problems. The urologist must be able to recognize these abnormalities quickly and address them before significant problems arise. Failure to do so may result in an increase in morbidity and mortality in the acutely ill patient or the surgical patient. In this section, we discuss the major critical disorders that may lead to increased bleeding.

RENAL FAILURE

Uremia can cause a coagulopathic state that can place patients in renal failure at risk for severe hemorrhage. The main hemostatic defect is complex and multifactorial but is primarily the result of impaired platelet function, which can manifest as an elevated bleeding time in laboratory testing. Investigations of the hemorrhagic tendency associated with uremia have mostly been performed in patients with chronic renal failure, and whether these findings can be extrapolated to acute renal failure is unclear.[21]

Uremic bleeding is mainly the result of impaired platelet–vessel wall interaction. Observed changes that are thought to contribute to this dysfunction include increased prostacyclin and nitric oxide production by the endothelium, abnormalities in vWF, and biochemical and functional platelet abnormalities.[22,23]

Anemia, often associated with renal failure, also plays a role in platelet dysfunction. Correction of anemia in uremic patients has been shown to improve or correct the prolongation of bleeding time. Improvement in coagulation studies was seen when the hematocrit was increased to 27–32% by transfusion of packed red blood cells or by stimulation of erythropoiesis with recombinant human erythropoietin.[24–27] Anemia related bleeding diathesis is not exclusive to uremia and can be found in anemia from other etiologies.[28]

The finding that acquired platelet dysfunction is partially corrected by hemodialysis suggests that accumulation of uremic toxins in the blood may contribute to the observed effects. Despite the hemorrhagic tendency, activation of coagulation has been demonstrated in uremic patients and is more prominent in those who are being treated with hemodialysis. The safest treatment to relieve uremic bleeding is administration of desmopressin (DDAVP), but its effect is often short-lived. High-dose intravenous (IV) conjugated estrogens can significantly improve the bleeding time and have a longer duration of action in most uremic patients.[29–32]

DISSEMINATED INTRAVASCULAR COAGULATION

DIC is a clinicopathologic syndrome characterized by systemic activation of the coagulation system. Of all acute causes of coagulopathy, it is potentially the most life-threatening. DIC is not a single entity, but rather the end product of a variety of underlying disorders, most commonly bacterial sepsis and malignancy in the urologic patient.[33–36]

Central to the pathogenesis of DIC is the unregulated and excessive generation of thrombin.[34] Normally, the cumulative effect of clot production, clot dissolution (fibrinolysis), and inhibition of clot activation is to produce a steady-state equilibrium of hemostasis. In DIC, excess thrombin is generated, resulting in the inappropriate activation of fibrinolysis and the shifting of the steady state to excessive clot dissolution. A secondary result is that fibrin thrombi are formed in the microvasculature, and platelets and RBCs are trapped and consumed. As the cycle continues, platelets, fibrinogen, and other clotting factors are consumed beyond the body's ability to compensate, and excessive bleeding ensues. It

should be clear from this description that DIC is initially a thrombotic process with secondary hemorrhage occurring only when platelets and clotting factors are sufficiently consumed and depleted. Approximately 10% of patients with DIC present with only thrombotic manifestations.[36]

Patients in whom DIC is suspected generally present with diffuse bleeding from several sites, petechiae or ecchymosis, hypoxemia, hypotension, or oliguria. In acute DIC, laboratory evaluation demonstrates variable degrees of thrombocytopenia, hypofibrinogenemia, and prolongation of PT and aPTT. Assays for fibrin split products (FSPs), fibrin degradation products (FDPs), or the D-dimer fragments of fibrin are generally markedly elevated. The D-dimer assay is theoretically more specific for DIC because this fragment is produced by the action of plasmin on polymerized fibrin.[37,38] Patients with malignant disease often have chronic, compensated DIC in which bleeding is minimal in the steady state, and these patients often present with normal PT/PTT, platelet, and fibrinogen test results. Patients in this subset demonstrate an elevation of FDPs, FSPs, or D-dimer. These patients are also at increased risk for significant bleeding following an insult resulting in activation of their clotting system, such as relatively minor surgical procedures.[36,39]

The diagnosis of DIC relies heavily on laboratory results, but overall the clinical picture must be considered. Of all the laboratory findings, thrombocytopenia, hypofibrinogenemia, and D-dimer fragments appear to be the most sensitive in making a laboratory diagnosis.[36–39] In addition to the coagulation abnormalities, microangiopathic hemolytic anemia is present with fragmented RBCs (schistocytes) on the peripheral blood smear.[36]

The primary management strategy in patients with DIC consists of aggressive basic supportive measures and prompt treatment of the underlying process causing the DIC.[33,36,40] When this is not possible, treatment of the underlying disease accentuates the DIC, or the DIC is progressing despite appropriate treatment of the underlying process, the general approach is to support the patient's hemostatic system with the transfusion of FFP, cryoprecipitate, or platelets.[36] The idea that this approach will add to the consumption coagulopathy has never been clinically proven. If hemorrhage is excessive, replacement with packed RBCs is advised. Use of heparin in DIC is controversial. Therapeutic heparin can be considered if thrombosis is the predominate manifestation and there is no significant bleeding that may be exacerbated by anticoagulation.[38,41]

PRIMARY FIBRINOLYSIS

Primary fibrinolysis is a condition in which the fibrinolytic pathway is activated independent of the activation of coagulation resulting in the pathologic degradation of fibrinogen and fibrin by plasmin. Fibrinolysis is associated with advanced and often metastatic prostate cancer and portends a very poor prognosis, even if significant bleeding is not present.[42,43] In patients with metastatic carcinoma, the tumor cells are presumed to release a substance that directly activates fibrinolysis.[35]

Patients do not typically present with gross bleeding but are at significant risk for hemorrhage resulting from hypofibrinogenemia. Marked thrombocytopenia should raise the suspicion of the development of DIC. The major laboratory discriminant between primary fibrinogenolysis and DIC is a normal level of D-dimer. Once active bleeding develops, it is very difficult to distinguish the two entities because fibrin is generated through the action of thrombin and lysis of fibrin produces D-dimer.[35]

Unlike in DIC, the treatment of choice of primary fibrinogenolysis is the use of antifibrinolytic agents, such as ε-aminocaproic acid or tranexamic acid.[35,42,44] Transfusion support with cryoprecipitate may also be given for severe hypofibrinogenemia. If DIC has developed, the use of antifibrinolytic agents in the absence of systemic anticoagulation (heparin) is contraindicated because of the risk of increased microvascular thrombosis. The best approach in individuals with primary hyperfibrinogenolysis secondary to malignant disease is often aggressive treatment of the underlying malignant condition. Caution should be used in balancing chemotherapy-related bone-marrow suppression with bleeding complications resulting from fibrinogenolysis.

VITAMIN K–RELATED DISORDERS

Liver disease and vitamin K deficiency are common causes of abnormal coagulation test results and clinical coagulopathy. The pathophysiology of these disorders is the decreased production of vitamin K–dependent clotting factors (factors II, VII, IX, X), protein C, and protein S. The liver is the major source of all coagulation proteins except factor VIII and vWF. Liver disorders may also produce abnormalities in fibrinolysis.[37,38] Primary vitamin K deficiency is extremely rare in healthy people. A wide variety of animal and plant sources can provide sufficient vitamin K, and the bacterial flora in the intestine is able to synthesize a significant portion of the required dietary vitamin K. Vitamin K is fat soluble, and therefore adequate bile salt circulation is necessary for absorption.

Vitamin K deficiencies can result from a wide range of conditions. These include, but are not limited to, the following:

1. Newborns, owing to poor transfer of vitamin K by the placenta and lack of vitamin K synthesis in the initially sterile intestine
2. Severe malnutrition or total parenteral nutrition
3. Extrahepatic biliary obstruction
4. Intestinal malabsorption syndromes
5. Broad-spectrum antibiotic use.

The liver also synthesizes factor V, which plays a critical role in fibrin generation. Significant impairment of hepatic synthetic function may result in the decreased production of any of these clotting factors despite normal vitamin K status.

Patients with liver disease or vitamin K deficiency initially have isolated prolongation of the PT resulting from a depletion of factor VII without any signs of clinically significant bleeding. Factor VII has the shortest half-life (6–10 hours) of the coagulation factors. In more severe deficiencies, the PTT can also be elevated because of depletion of factors II, IX, and X. A marked reduction in fibrinogen solely on the basis of decreased synthesis is an ominous sign and suggests very severe liver disease. Patients with long-standing liver disease develop portal hypertension, which may result in splenic pooling of platelets. A valuable assessment of

liver synthetic function is the measurement of albumin or cholesterol.

In a patient with vitamin K deficiency and no evidence of active bleeding, observation with repletion of vitamin K is indicated. Vitamin K may be administered orally, subcutaneously, intramuscularly, or intravenously. Subcutaneous injection is not favored due to variable response and absorption. The fastest route is intravenous injection (1 mg/day), but this carries a risk of anaphylaxis and therefore should be done slowly and in a monitored setting.[45] Oral vitamin k is given at a dose of 5–10 mg/day; improvement is usually seen within 24 hours.[46]

The response to vitamin K may be poor in the presence of liver disease. Patients who fail to respond to vitamin K, who demonstrate increasing abnormalities of PT or PTT, or who are to undergo an invasive procedure may be treated with FFP infusions. Given the short half-life of factor VII, aggressive support with FFP every 6 hours in the perioperative period is generally necessary to produce sustained correction in clotting.[47]

MASSIVE TRANSFUSION SYNDROME

Massive transfusion syndrome results from the replacement of total body blood volume in less than 24 hours without the concomitant transfusion of platelets and FFP, usually in the setting of trauma.[48] This situation leads to dilutional coagulopathy because stored RBCs contain no viable platelets and are usually deficient in coagulation factors. This dilution results in a clinical and laboratory picture resembling DIC.[48] This diagnosis should be suspected in any patient who presents with bleeding, prolonged PT, prolonged PTT, and thrombocytopenia after receiving >5 units of blood. The key element in making the diagnosis is the transfusion history.

Treatment of this disorder is accomplished by replenishment of clotting factors and platelets through administration of FFP and platelet transfusions. The best treatment is prevention by transfusion of 1 unit of FFP and platelets for every 5 units of packed RBCs given. In individuals with continued or excessive blood loss, empirical treatment with FFP or platelets may be advisable. In the absence of uncontrolled or continued bleeding, it is acceptable to hold the use of FFP and platelets unless they are clinically indicated for postoperative bleeding.[48]

Anticoagulated Patient

Patients receiving chronic anticoagulation therapy who require a urologic procedure represent a challenge to the urologist. Perioperative management of these patients should be aimed at minimizing both surgical and medical risks. To accomplish this goal, the urologist must have an understanding of the indication for anticoagulation therapy, the consequence of withholding the therapy, and the pharmacologic mechanism of action of the particular anticoagulation medication.[42] Perioperative management of anticoagulation or antiplatelet therapy should be determined by the patient and a therapeutic team made up of the urologist, anesthesiologist, cardiologist and primary care physician. The number of available antiplatelet and anticoagulant agents has increased significantly over the last few years. The following tables will provide an overview of the available medications (see Tables 4.3–4.5).

The most common indications for chronic anticoagulation include venous thromboembolism (VTE), mechanical prosthetic heart valves, chronic atrial fibrillation, and coronary stents, particularly drug-eluting stents (DES). Discussion of VTE is addressed later in this chapter. Mechanical prosthetic heart valves require anticoagulation secondary to the risk of thrombotic complications, including systemic embolization and occlusive thrombosis. Patients with atrial fibrillation require anticoagulation because of a six times higher rate of stroke.[42]

ANTIPLATELET THERAPY

The most commonly encountered antiplatelet medications include aspirin (ASA) and the $P2Y_{12}$ receptor blocking agents (e.g., clopidogrel and prasugrel). See Table 4.3 for an overview of antiplatelet medications. These drugs are used for secondary prevention in patients with cerebrovascular, coronary, and peripheral vascular disease. Antiplatelet medications are also used after percutaneous coronary intervention (PCI) with placement of endovascular stent to prevent stent thrombosis.

ASA exerts its anticoagulant effect by irreversibly inhibiting platelet cyclooxygenase 1 (COX-1), which inhibits thromboxane A production and reduces platelet aggregation. This effect is irreversible and lasts for the life of the platelet, which is approximately 7 to 10 days. Therefore patients taking ASA who are undergoing an elective procedure should discontinue ASA for approximately 7–10 days before the procedure.[49] The most common side effects of aspirin are gastrointestinal and can manifest as minor dyspepsia or major gastritis, ulcers, and bleeding.

The thienopyridines or $P2Y_{12}$ receptor blockers target an integral ADP receptor on the surface of platelets. The thienopyridines include ticlopidine, clopidogrel, and prasugrel (Table 4.4). This potent irreversible blockade prevents ADP-induced platelet aggregation. The thienopyridines can also cause gastrointestinal side effects, but also major hematologic complications (neutropenia, thrombocytopenia, and thrombotic thrombocyptopenic purpura). These major effects usually manifest within the first 3 months of initiation of these medications. $P2Y_{12}$ receptor blockers should be stopped 5–7 days prior to a procedure to reduce the risk of bleeding.[49,50]

Percutaneous coronary intervention is now very common in treatment of obstructive coronary artery disease. During PCI either bare metal stents (BMS) or DES are often placed. Dual antiplatelet therapy (DAPT) with ASA and a $P2Y_{12}$ receptor blocker are used to decrease risk of stent thrombosis. Risk of stent thrombosis in the perioperative period is highest in the first 4–6 weeks after stent implantation. DES decrease the risk of re-stenosis but have longer periods of increased risk for in-stent thrombosis. The American College of Cardiology (ACC) and the American Heart Association (AHA) task force created practice guidelines in 2014 for perioperative cardiovascular management of patients undergoing noncardiac surgery. Elective noncardiac surgery should be delayed 14 days after PCI with balloon angioplasty (no stent placement), 30 days for BMS

Table 4.3 Antiplatelet Medications

Class	Drugs	Mechanism of Action	Common Indications	Dose	Side Effects
Salicylates	Acetylsalicylic acid (Aspirin)	Irreversible platelet COX-1 inhibition	Secondary prevention in patients with cerebrovascular, coronary, and peripheral vascular disease	75–325 mg PO daily	GI (dyspepsia, gastritis, ulcers, bleeding), hepatic and renal toxicity in overdose
Thienopyridines	Clopidogrel (Plavix), Ticlopidine (Ticlid), Prasugrel (Effient)	Irreversibly blocks platelet ADP receptor ($P2Y_{12}$ receptor) leading to disruption of platelet aggregation	Secondary prevention in cerebrovascular, coronary, and peripheral vascular disease (in combination with ASA) to prevent post cardiac and peripheral stent thrombosis or in cases of unstable angina	Clopidogrel 75 mg PO daily (commonly started with loading dose)	GI thrombocytopenia TTP
Dipyridamole	Aggrenox (combination extended-release dipyridamole and low-dose Aspirin)	PDEi causing increased intracellular platelet cAMP leading to platelet inhibition	Stroke prevention in patients with history of TIA	200 mg dipyridamole – 25 mg ASA PO twice daily	GI, headaches, facial flushing, dizziness, hypotension
Glycoprotein IIb/IIIa receptor antagonist	Abciximab (ReoPro), Eptifibatide (Integrillin), Tirofiban (Aggrastat)	Targets the glycoprotein IIb/IIIa receptor on surface of platelets limiting aggregation	Patients with acute myocardial infarction or planned percutaneous intervention tirofiban/eptifibatide – high-risk patient with unstable angina	Intravenous bolus followed by infusion	Immune-mediated thrombocytopenia

ASA, aspirin; TTP, thrombotic thrombocytopenic purpura; TIA, transient ischemic attack; PDEi, phosphodiesterase inhibitor; cAMP, cyclic adenosine monophosphate; PO, per os; GI, gastrointestinal; ADP, adenosine diphosphate

(Adapted from Braunwald E, Bonow RO, editors. Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine. 9th ed. Philadelphia: Saunders; 2012. 1961)

Table 4.4 Parenteral Anticoagulants

Class	Drugs	Administration	Mechanism of Action	Common Indications	Side Effects
Heparin	Heparin	Intravenous or subcutaneous	Activation and enhancement of antithrombin activity	Acute coronary syndrome, atrial fibrillation, prevention and treatment of venous thromboembolism, treatment of pulmonary embolus	Elevation of transaminases, HIT, osteoporosis
Low-molecular-weight-heparin	Enoxaparin (Lovenox), dalteparin (Fragmin), tinzaparin (Innohep)	Subcutaneous injection	Activation of antithrombin causing inhibition of factor Xa	Similar to heparin	HIT, osteoporosis
Selective factor Xa inhibitors	Fondaparinux (Arixtra)	Subcutaneous injection	Catalyzes inhibition of factor Xa by antithrombin	Similar to heparin, appears to be effective in treating HIT	Bleeding
Direct thrombin inhibitors	Bivalirudin (Angiomax), argatroban	Intravenous or subcutaneous	Bind directly to thrombin to block substrate interaction	Similar to heparin, treatment of HIT	Back pain, nausea, headache, and hypotension

HIT, heparin induced thrombocytopenia

(With permission from Braunwald E, Bonow RO, editors. Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine. 9th ed. Philadelphia: Saunders; 2012. 1961)

implantation, and 365 days after placement of a DES. Elective noncardiac surgery can be considered after 180 days if the risk of surgical delay is greater than the risk of ischemia or stent thrombosis. In patients undergoing urgent noncardiac surgery during the first 4–6 weeks after stent implantation (BMS or DES), DAPT should be continued if the risk of bleeding is not too great. If the bleeding risk is deemed too high, then ASA should be continued if possible and the $PG2Y_{12}$ platelet receptor inhibitor should be restarted as soon as possible. The benefit of aspirin use in prevention of perioperative ischemic complications in a patient without previous cardiac stenting is unclear. The continuation of aspirin in a patient with a high-risk coronary artery disease or cerebrovascular disease with no history of coronary stenting may be reasonable if the risks of an ischemic event outweigh the risks of bleeding.[51]

The American Urologic Association (AUA) and the International Consultation on Urological Diseases (ICUD) released a 2014 review paper covering anticoagulation and antiplatelet therapy in urologic practices. Some of the urology-specific recommendations regarding antiplatelet medication will be listed below. Patients with cardiac risk

Table 4.5 Oral Anticoagulants

Class	Drugs	Mechanism of Action	Common Indications	Side Effects	Half-Life (Hours)
Vitamin K antagonist	Warfarin (Coumadin)	Interferes with synthesis of vitamin K–dependent clotting factors	Stroke prevention in patients with atrial fibrillation, prevention of thrombotic or thromboembolic events in patients with prosthetic heart valves, prevention and treatment of deep venous thrombosis	Skin necrosis	36–42
Factor Xa inhibitor	Rivaroxaban (Xarelto), apixaban (Eliquis)	Reversible inhibition of active site of factor Xa	Stroke prevention in patients with nonvalvular atrial fibrillation, prevention and treatment of deep venous thrombosis	Gastrointestinal bleeding	9–14
Direct thrombin inhibitor	Dabigatran etexilate (Pradaxa)	Reversible inhibition of active site of factor IIa (thrombin)	Stroke prevention in patients with nonvalvular atrial fibrillation		12–17

(Adapted from Braunwald E, Bonow RO, editors. Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine. 9th ed. Philadelphia: Saunders; 2012. 1961)

factors on low-dose aspirin by itself can continue the medication in the perioperative period without increased risk of bleeding. Patients taking low-dose aspirin without any specific indication can hold their aspirin for an elective procedure until directed to restart by the surgical team. Prostate biopsy can be performed safely on a patient taking low-dose aspirin, but with an increased risk of minor bleeding. In general, the continuation of aspirin for urologic procedures in the perioperative period is associated with a minor risk of increased bleeding without major consequences and is not associated with an increased risk of transfusion. Transurethral resection of the prostate, shockwave lithotripsy, and percutaneous renal surgery are probable exceptions to this rule.[52]

ANTICOAGULATION THERAPY

Full-dose or therapeutic anticoagulation can be achieved with vitamin K antagonists (warfarin) or the novel oral anticoagulants (NOACs), which include direct thrombin inhibitors and factor Xa inhibitors. These medications are used to prevent thrombotic and thromboembolic events in high-risk patients and in treatment or prevention of deep venous thrombosis. Again, perioperative choices for the management of anticoagulation should be made in conjunction with other providers and must weigh the risks of bleeding against the risk of a thrombotic event.

Warfarin exerts its anticoagulant effect by inhibiting vitamin K–dependent procoagulation factors II, VII, IX, and X and anticoagulant proteins C and S. Warfarin's effect usually occurs 2–3 days after initiation of therapy because of the prolonged half-life of the different procoagulant factors; factor II has the longest half-life (72 hours). In the past, the PT was used to measure the effect of warfarin, but because of variability in PT measurements the INR (international normalized ratio) is currently used. Most procedures can be performed safely when the INR is 1.4 or less. Warfarin is used in patients with prosthetic heart valves, atrial fibrillation, and a history of stroke as well as in preventing recurrent myocardial infarction and death in patients with an acute myocardial infarction.[53] However, the most common indication for warfarin therapy is management of patients with VTE.

The NOACs are new alternatives to warfarin (Table 4.5). These medications target thrombin or factor Xa directly and reversibly bind the active site of the coagulation factor. Unlike warfarin, the onset of action is rapid and routine monitoring is not required. These medications should be discontinued >48 hours prior to a procedure.[51] A longer interval of discontinuation should be used in the setting of renal impairment.[50] Routine monitoring of the levels of anticoagulation are not performed, but qualitative assessment of anticoagulation can be performed with prothrombin time for factor Xa inhibitors and activated partial thromboplastin time for direct thrombin inhibitors. Apixaban has a limited effect on PT; anti-factor Xa assays can be used to determine the anticoagulant activity. There are no current antidotes or reversal agents for these medications. A patient who is experiencing severe hemorrhage while taking a NOAC should be managed with fluid resuscitation and repletion of blood products by transfusion as needed. If the last dose of anticoagulant was taken within a 4–6 hour window, then activated charcoal may help reduce absorption. There is no substantial evidence to support the effectiveness of the use of procoagulant factors at this time. Dialysis may be used to remove dabigatran from the circulation but will not remove the highly protein bound rivaroxaban or apixaban.[50]

The management of patients taking warfarin who require an invasive procedure depends on the procedure, the risk of bleeding, and the risk of thromboembolism once the warfarin is stopped. The ACC/AHA perioperative guidelines address management of anticoagulation in patients with atrial fibrillation and prosthetic heart valves.

Patients with atrial fibrillation undergoing a high-risk surgical procedure should stop warfarin 5 days prior to the procedure to allow the INR to normalize. Therapy should be restarted 12 to 24 hours after the procedure if the risk is acceptable.[52]

Patients with prosthetic valves who are at lower risk for thrombosis such as those with bileaflet mechanical aortic valve replacements and no risk factors (atrial fibrillation, previous thromboembolism, left ventricular dysfunction, older generation thrombogenic valve, mechanical tricuspid valves, or multiple mechanical valves) can stop warfarin 48 to 72 hours prior to a procedure to allow the INR to correct,

and restart therapy within 24 hours after the procedure if safe.[51]

Patients with prosthetic valves who are at high risk for a thromboembolic event, including patients with a mechanical mitral valve or an aortic valve replacement with any risk factor (atrial fibrillation, previous thromboembolism, left ventricular dysfunction, hypercoagulable state, older generation thrombogenic valves), should discontinue warfarin 3–5 days before admission and start bridging anticoagulation with unfractionated or low-molecular-weight heparin (LMWH).[51] One consideration is patients with renal failure, in whom LMWH is contraindicated. If emergency surgery is required, then patients receiving warfarin therapy can receive FFP. Vitamin K should be used with caution to reverse the effect of warfarin because it can complicate the re-initiation of warfarin therapy.[54]

Heparin acts by inactivating free thrombin through its interaction with antithrombin III (AT III). The inactivation of thrombin prevents the conversion of fibrinogen to fibrin. Heparin also inactivates factors Xa and IXa of the coagulation cascade. Heparin's anticoagulant effect is monitored by aPTT or anti-factor Xa assay (also called anti-Xa assay), which measures the inhibitory activity of heparin on the activated form of factor Xa. Heparin should be discontinued 3–4 hours before a procedure. If reversal is necessary on an emergency basis, protamine can be given.

Finally, patients with thromboembolic disease that has occurred beyond 3–6 months should be managed by discontinuing anticoagulation 3–5 days preoperatively and resuming it as soon as possible postoperatively. Patients with a history of a more recent thromboembolic event should be managed with concurrent heparin anticoagulation during the discontinuation of warfarin.[53,54] If history of DVT is an issue prior to surgery and bleeding risk and/or pulmonary embolism risk is high, consideration should be given to placement of an IVC filter prior to surgery after consultation with vascular surgery.

Management of Intraoperative Bleeding

On occasion, the urologist is faced with a patient who has extreme intraoperative coagulopathy. This condition has many possible causes, and it is imperative for the surgeon to identify the appropriate factors. When the operative field is infected, such as in abscess drainage or resection of xanthogranulomatous pyelonephritis, coagulopathy should be a clue to progressive intraoperative sepsis. In individuals with excessive surgical bleeding, dilutional coagulopathy is a likely source. Finally, in patients with known abnormalities of hepatic synthetic function, the bleeding may be a function of the underlying disease state. The immediate management of such patients varies according to the cause of bleeding.

In patients with dilutional coagulopathy or transfusion reaction, empirical replacement of clotting factors with administration of FFP, cryoprecipitate, or platelets may be enough to slow bleeding and allow completion of the surgical procedure. The patient's core temperature should be maintained because hypothermia may worsen the bleeding. Devices such as warming blankets, as well as warm irrigation of the surgical field, may allow rapid improvement in core temperature in such a setting. In patients with consumptive coagulopathies, such efforts may be of little help. In these cases, the surgeon's effort should be focused on prompt completion of the procedure with maximal drainage of the infected cavity, to minimize ongoing bacteremia.

In the absence of visible arterial bleeding, exhaustive efforts to control the bleeding with cautery or ligature are often unsuccessful, and liberal use of packing should be implemented. Extensive efforts to achieve hemostasis only delay the completion of the procedure and, indirectly, worsen the coagulopathy through progressive blood loss and hypothermia. On completion of the procedure, widespread coagulation with devices such as the argon beam coagulator can be useful as long as they do not delay completion of the procedure.

On rare occasions if the patient is unstable the procedure must be aborted or packing may be left in place even after completion of the procedure. When this is necessary, packing is generally left in place with the wound closed in a single layer. The patient is then transported to the intensive care unit for resuscitation and correction of coagulopathy before reoperation and removal of packing, usually 24 to 48 hours later. In cases of extirpative surgical procedures, organ resection should be completed if possible to allow more prompt resolution of coagulopathy. Reconstruction can then be carried out at the time of re-exploration. In patients with active infection, drainage or resection of infected tissue is extremely important before the procedure is aborted because ongoing infection may perpetuate the coagulopathy. New infection is a concern in aborted procedures, and the patient should be maintained on broad-spectrum antibiotics while packing materials are in place.

Problems of Increased Coagulation

HYPERCOAGULABLE STATE

Patients with a history of recurrent or spontaneous venous thrombosis may have an underlying *familial or acquired hypercoagulable state* (Table 4.6).[55,56] Historically, it was thought that underlying hereditary defects were the source of <10% of such cases.[56] More recently, it was determined that in fact >50% of such cases have a specific underlying cause. The coagulation cascade is influenced by certain regulatory factors. Abnormalities of these factors may increase the risk of thrombosis and include deficiencies of antithrombin (AT) III, protein C, and protein S. Activated protein C (APC) resistance (factor V Leiden mutation) was discovered to account for the majority of diagnosable coagulation defects (Table 4.7).[57–60] Factor V Leiden occurs with an estimated frequency of 5% in the general population of European ancestry.[61,62]

Physiology

Most coagulation proteins are serine proteases that act sequentially on one another. These proteins are regulated by another series of proteins called *serapins* (serine protease inhibitors). Serapins may be activated under normal

Table 4.6 Familial or Acquired Disorders Leading to Hypercoagulable State

Familial	Acquired
Antithrombin III deficiency	Malignant disease
Protein C deficiency	Regulatory protein deficiency (malnutrition/nephrotic syndrome)
Protein S deficiency	Acute-phase reactants (trauma/surgery)
Activated protein C resistance	Antiphospholipid syndrome
Factor V Leiden	Myeloproliferative disorders
Abnormal factor V cofactor activity	Heparin-associated thrombocytopenia
Hypoplasminogenemia	Disseminated intravascular coagulation
Abnormal plasminogen	Oral contraceptives
Plasminogen activator deficiency	Pregnancy/postpartum state
Dysfibrinogenemia	
Factor XII deficiency	
Abnormal platelet reactivity	

Table 4.7 Prevalence of Hereditary Disorders Leading to Hypercoagulability

Disorder	Prevalence (%)
Elevated Factor VIII:c levels	11
Factor V Leiden	Whites 4–7 Nonwhites 0–1
Prothrombin G20210A	Whites 2–3 Nonwhites 0–1
Antithrombin III, protein C or S deficiency	1

(Adapted from Middeldorp S, Coppens M. Hereditary thrombophilia. In: Kaushansky K, Lichtman MA, Prchal JT, Levi MM, Press OW, Burns LJ, et al., editors. Williams Hematology, 9e [Internet]. New York, NY: McGraw-Hill Education; 2015.)

homeostatic situations, in stress conditions, or as part of administered therapy. Serapin deficiencies may cause the hypercoagulable state. The best-studied serapin is AT III, a heparin cofactor that allows heparin to inactivate factors II, IX, XI, and XII. A decrease in the concentration of AT III predisposes patients to thrombosis by allowing uncontrolled activity of the majority of coagulation factors. AT III deficiency is responsible for hypercoagulability in 2–4% of studied patients, and it is present in 0.2–0.4% of the general population.[53] In addition to regulation by serapins, the clotting cascade is influenced by a complex group of receptors at the endothelial surface termed *thrombomodulins*. These receptors function as anticoagulants because of their ability to neutralize thrombin on the endothelial surface. Once formed, the thrombin-thrombomodulin complex activates a vitamin K–dependent factor called *protein C*, which metabolizes activated factors V and VIII and thus suppresses coagulation. This activation is facilitated by another vitamin K–dependent factor called *protein S*, which also functions to metabolize activated factors V and VIII. Deficiencies in proteins C or S may result in a thrombotic tendency, are observed in 2–5% of hypercoagulable patients, and are present in approximately 0.5% of the general population.[55,56,60]

For APC to exert its control on activated factor V, it must first attach to and then cleave this factor. A mutation in factor V, called *factor V Leiden*, has been identified that results in the inability of APC to cleave factor V, a condition referred to as *APC resistance*. This abnormality accounts for approximately 90% of cases of APC resistance and has a prevalence of approximately 5% in the general population.[57–60,63,64]

Deficiencies of AT III, protein C, and protein S, as well as APC resistance, are all inherited in an autosomal dominant fashion, and deficiencies of these proteins have an incidence of <1% each.[55] APC resistance is present in 3–8% of the population.[55,60] The presence of APC resistance increases the likelihood of a simultaneous additional inherited disorder. In such cases, the risk for thrombosis is dramatically increased compared with the risk in individuals with APC resistance alone.[65–69] Coexisting acquired conditions (see Table 4.6), as well as immobilization, trauma, pregnancy, malignant disease, hormone replacement therapy, and surgery, also significantly add to the risk for thrombosis in individuals with hereditary hypercoagulable states.[55,70]

An acquired condition that has been increasingly recognized as a common cause of thrombosis is the *antiphospholipid syndrome*, which is present in 2–3% of the general population. Antiphospholipids predispose patients to both arterial and venous thrombosis.[71] The diagnosis involves the detection of lupus anticoagulant or anticardiolipin antibodies in conjunction with arterial and venous thromboses or thrombocytopenia.[55,63,64] Individuals with lupus anticoagulant may present with an elevation of serum aPTT. The mechanism of thrombosis in antiphospholipid syndrome, however, has not been well delineated.[64,72,73]

Evaluating the Hypercoagulable Patient

Screening for an underlying coagulation abnormality in cases of venous thrombosis should be performed in the presence of any of the following situations:

1. Family history of thrombosis
2. Thrombosis at an early age (<45 years)
3. Recurrent thrombosis, especially without precipitating factors
4. Recurrent thrombosis despite adequate anticoagulant therapy
5. Thrombosis at an unusual site
6. Elevated aPTT (lupus anticoagulant), hematocrit, white blood cells, and platelets
7. Apparent warfarin-induced skin necrosis.

Several additional indications suggest the need to test for antiphospholipid antibodies. These indications include a history of recurrent fetal loss, venous or arterial thrombosis associated with thrombocytopenia, and thrombosis associated with neurologic abnormalities such as stroke or transient ischemic attacks. A specific cause of spontaneous venous thrombosis is found in ≤50% of outpatients, but all individuals should be evaluated because of the potentially lethal consequences of an untreated underlying abnormality.[63]

Abnormalities of AT III, protein C, or protein S in screened individuals can manifest with either a normal or deficient level. Individuals with normal levels may have dysfunctional or inactive forms of these proteins, thereby resulting in a clinically deficient state. A comprehensive discussion of specific assays is beyond the scope of this chapter, but for the aforementioned reasons, functional assays are initially more informative than antigenic assays that simply measure the presence or absence of the factor. Ideally, the patient should not be in an active thrombotic state or taking anticoagulants at the time of testing.

Whenever possible, anticoagulant therapy should be discontinued several weeks before testing because warfarin and heparin can interact with the various assays. When concern exists that a patient is still at risk for thrombosis if anticoagulation is discontinued, it is possible to continue anticoagulation while testing for certain hypercoagulable states. Deficiencies in AT III, lupus anticoagulant, and anticardiolipin antibodies, as well as APC resistance (in factor V–deficient plasma), can be detected during warfarin administration. Additionally, protein C or S deficiencies or anticardiolipin antibodies can be tested for while patients are receiving heparin (Table 4.8).[63]

A positive test result should be confirmed before the diagnosis of an inherited deficiency is made. To confirm the diagnosis of the antiphospholipid syndrome, antibodies must be shown to be present on two occasions >3 months apart.

Management

Acute thrombosis with an underlying hypercoagulable condition requires treatment as discussed in the next section, but some special considerations should be kept in mind in patients with known hypercoagulable states and an acute thrombotic event. After the initial therapy and the recommended 3–6 months of therapy with anticoagulation, the question remains as to which patients require continued anticoagulation. The number of sites involved, the severity of thrombosis, the presence of recurrent thrombosis, and whether the thrombosis was spontaneous or secondary to a precipitating event should all be taken into consideration. Special attention must be paid to such factors as reproductive status and potential risks for immobilization or trauma.

Table 4.8 Effects of Anticoagulants on Functional Assays for Hypercoagulable States

	Effect of Anticoagulant	
Functional Assay	**Heparin**	**Warfarin**
Antithrombin III	Decrease	No effect
Protein C	No effect	Decrease
Protein S	No effect	Decrease
Activated protein C resistance	False-positive result	Modified assay may avoid interaction
Lupus anticoagulant	Possible false-positive result	Modified assay may avoid interaction
Anticardiolipin antibodies	No effect	No effect

For patients with antiphospholipid syndrome, available studies suggest that lifelong anticoagulant therapy should be considered in the setting of any arterial or venous thrombotic event.[64,72] Conversely, lifetime anticoagulation is recommended only for patients with two or more thromboembolic events following the diagnosis of an inherited deficiency. Finally, in asymptomatic adults with hereditary deficiencies, short-term prophylaxis with heparin (subcutaneous or LMWH) should be considered when the risk of thrombosis is increased, such as during prolonged bed rest, surgery, or trauma.[55,56,63]

DEEP VENOUS THROMBOSIS AND PULMONARY EMBOLISM

Thromboembolic disease, in particular deep venous thrombosis (DVT) and pulmonary embolism (PE), is a significant cause of morbidity and mortality in surgical patients. DVT accounted for nearly 100,000 hospital visits in 2000, according to the Centers for Medicare and Medicaid Services.[54] Approximately 5 million cases of DVT, 500,000 to 630,000 cases of PE, and 200,000 cases of fatal PE occur annually.[51] Patients undergoing abdominal or pelvic surgery for cancer are at a high risk for these complications. In a review of patients who underwent pelvic surgical procedures without prophylaxis, Kibel and associates reported a DVT incidence rate of approximately 30%, a PE incidence rate of 10%, and a fatal PE rate of 5%.[74] Investigators have reported that 1–5% of patients undergoing major urologic surgical procedures have symptomatic VTE.[75]

The risk factors for venous thrombosis can be thought of in the context of Virchow's triad for the pathophysiology of thrombus formation:

1. Stasis
2. Hypercoagulability
3. Intimal injury.

Risk factors include advanced age (>60 years old), obesity, history of previous DVT, prolonged immobility, pregnancy, malignant disease, fracture, estrogen use, major medical conditions leading to venous stasis (congestive heart failure, nephrotic syndrome, sepsis, myocardial infarction, inflammatory bowel disease, erythrocytosis, myeloproliferative disorder), and thrombophilia.[68,76,77] Importantly these risk factors are additive. Wheeler showed that patients with no risk factors had an 11% and 1% rate of DVT and PE, respectively, whereas those patients with one risk factor had a 24% and 4% rate, and finally those with four risk factors had a much higher risk of 100% and 67%.[78]

Thrombus formation is believed to occur during the surgical procedure.[78,79] Investigators have proposed that the likelihood of thrombus formation increases with the duration of anesthesia, especially if it exceeds 1 hour.[80,81] This finding seems to be related to an increase in venous stasis secondary to prolongation of intraoperative muscle relaxation.

Urologic patients, by the nature of the diseases for which they are surgically treated, often have multiple risk factors for thromboembolic disease including advanced age, malignant disease, and prolonged operative time. The incidences of DVT and PE have been examined in various urologic procedures. Historically, Colby in 1948 reported a 6.26%

thromboembolic rate and a 2.64% fatal PE rate in patients undergoing open prostate surgical procedures.[82] Although prophylaxis has reduced the rate of thromboembolic events in urologic surgery, the rates still remain significant. The rate of events has been reported as 0.24–1.5% after nephrectomy,[83,84] 1.3–6.2% after radical prostatectomy,[85,86] and 0.52–5.9% after radical cystectomy.[87,88]

The challenge of diagnosing DVT stems from the nonspecific nature of its clinical presentation. The classic triad of pain, swelling, and erythema can be found in both patients with and without DVT. The classic Homans sign, calf pain on dorsiflexion of the foot, is found in only 10% of patients with DVT.[78] In view of these findings, objective testing is required to confirm the diagnosis before treatment, particularly because the treatment of thromboembolic disease is not without its own additional complications. Once DVT is suspected, compression ultrasonography of the proximal veins or duplex ultrasonography should be performed. Compression ultrasonography has a sensitivity of >90% for detecting proximal vein thrombosis.[89,90] It is less invasive than the gold standard diagnostic test, contrast venography, and is more accurate than impedance plethysmography.[76] If the initial ultrasound finding is abnormal, then a diagnosis of DVT can be comfortably made. Conversely, when the test result is normal, one cannot completely rule out the possibility of a DVT. Ginsberg, in a review of DVT management, recommended a repeat ultrasound study for those patients with clinically suspected DVT who had normal findings on their initial ultrasound examination.[76]

The diagnosis of acute PE is also difficult given the wide range of presentations.[59,79,80] More recent approaches, such as use of the Wells criteria, have suggested using a D-dimer test and categorizing patients as having a low, intermediate, or high probability of PE (Table 4.9).[90,91] When the index of suspicion is high, particularly in patients in the postoperative period, a spiral computed tomography (CT) scan with IV contrast is warranted and is considered by most clinicians to be the standard initial diagnostic test.

At present, we often employ spiral chest CT as a first test for PE. If results are negative, then we proceed with pulmonary angiography only if a strong clinical suspicion still exists for PE. A potential shortcoming of both spiral CT and pulmonary angiography is the need for a large bolus of IV or intraarterial contrast material. In individuals with preexisting renal compromise, a ventilation/perfusion scan is an option to consider.

Table 4.9 Wells Criteria

Criteria	Points
Clinical signs of DVT	+ 3
Alternative diagnosis less likely than PE	+ 3
Previous PE or DVT	+ 1.5
Heart rate >100 beats per min	+ 1.5
Recent surgery or immobilization	+ 1.5
Hemoptysis	+ 1
Malignancy (current or treated in the last 6 months)	+ 1
Score by Model	**PE Rate Overall**
<2 (low)	3.6%
2–6 (moderate)	20.5%
>6 (high)	66.7%

DVT, deep venous thrombosis; PE, pulmonary embolism
(Adapted from Wells PS, Anderson DR, Rodger M, et al. Derivation of a simple clinical model to categorize patient's probability of pulmonary embolism: increasing the model's utility with the SimpliRED D-dimer. Thromb Haemost. 2000 Mar;83(3):416-20.)

Management

The goals of treating thromboembolic disease are to prevent further propagation of the thrombus, to prevent embolization of the thrombus, and in certain situations to promote fibrinolysis. Once the diagnosis is made, then anticoagulation therapy should be instituted unless a contraindication exists. If the patient is hemodynamically unstable or has extensive ileofemoral DVT, cardiac and vascular surgical consultation should be considered for possible intervention.

If the patient is not hemodynamically unstable, then therapeutic anticoagulation usually with heparin should be instituted immediately on confirmation of DVT. Various regimens for the administration of IV unfractionated heparin have been developed and are based on weight or dose titration nomograms.[76] An aPTT of 1.5 to 2.5 times the control is recommended. Furthermore, attempts should be made to achieve therapeutic aPTT values as rapidly as possible because persistent subtherapeutic values likely increase the risk of DVT recurrence.

Warfarin therapy is started 24 hours after heparin therapy and is monitored by INR with a goal of 2.0 to 3.0 time the control. The clinician should confirm that the patient has no evidence of major bleeding with a therapeutic aPTT before warfarin therapy is instituted. Heparin therapy can be discontinued once therapeutic levels of INR have been achieved for 2 days. The duration of treatment is determined by the risk for future thromboembolic disease. Patients with a first episode of thromboembolic disease and a reversible risk factor such as surgery should be treated for 6 weeks to 3 months (depending on the severity of the episode). As described later, patients with idiopathic thromboembolic disease should be treated for 3 to 6 months. Longer and, in certain instances, indefinite treatment is recommended in patients with a predisposition for recurrent venous thrombus.

Complications of heparin therapy include bleeding, thrombocytopenia with and without thrombosis, osteoporosis, skin necrosis, and less common complications including anaphylaxis, hypoaldosteronism, and alopecia.[68,92] Similar complications are associated with warfarin therapy; bleeding is the most common. Particular attention should be paid to concomitant medications that may interact with warfarin and affect INR, the most prevalent of which are fluoroquinolones, macrolides, and sulfonamides in the treatment of urologic patients.[93,94]

Because of potential complications, alternative anticoagulation regimens have been sought. Several studies have been conducted in the past 2 decades to evaluate LMWH.

Table 4.10 American Urological Association Prophylaxis Recommendations

Patient Risk Stratification	
Low risk	Minor* surgery in patients <40 years with no additional risk factors
Moderate risk	Minor* surgery in patients with additional risk factors Surgery in patients aged 40–60 years with no additional risk factors
High risk	Surgery in patients >60 years Surgery in patients aged 40–60 years with additional risk factors (prior venous thromboembolism, cancer, hypercoagulable state)
Highest risk	Surgery in patients with multiple risk factors (age >40 years, cancer, prior venous thromboembolism)
*For the purposes of this table, minor surgery is defined as a procedure with a relatively short operating time in which the patient is rapidly ambulatory.	
Venous Thromboembolism Prophylaxis Recommendations	
Level of risk	Prophylactic treatment
Low risk	No prophylaxis other than early ambulation
Moderate Risk	Heparin 5000 units every 12 hours subcutaneous starting after surgery OR *enoxaparin 40 mg (Cr Cl 30 mL/min =30 mg) subcutaneous daily OR pneumatic compression device if risk of bleeding is high
High risk	Heparin 5000 units every 8 hours subcutaneous starting after surgery OR enoxaparin 40 mg (Cr Cl 30 mL/min 30 mg) subcutaneous daily OR pneumatic compression device if risk of bleeding is high
Very high risk	Enoxaparin 40 mg (Cr Cl 30 mL/min 30 mg) subcutaneous daily and adjuvant pneumatic compression device, OR Heparin 5000 units every 8 hours subcutaneous starting after surgery and adjuvant pneumatic compression device

Enoxaparin dose may vary with patient weight.
(Adapted from Forrest JB, Clemens JQ et al. AUA Best Practice Statement for the prevention of deep vein thrombosis in patients undergoing urologic surgery. J Urol. 2009 Mar;181(3):1170-7.)

LMWHs are synthesized from larger unfractionated heparin molecules by enzymatic or chemical depolymerization.[95–98] The advantages of LMWH include superior bioavailability, lower incidence of bleeding, lower incidence of heparin-induced thrombocytopenia, ease of administration and monitoring (subcutaneous once or twice daily), and the availability of outpatient use.[95,96] Several trials comparing LMWH with unfractionated heparin concluded that LMWH significantly reduced recurrence, had a superior relative risk reduction of thromboembolic complications, and incurred a statistically significant reduction in bleeding.[96,99] Although the actual cost of LMWH is 10 to 20 times that of unfractionated heparin, the potential lower complication rates, the reduced need for laboratory and hospital monitoring, and the availability of outpatient treatment may make LMWH a more cost-effective alternative. For these reasons, LMWH is preferable to unfractionated heparin in most settings.[96] The novel oral anticoagulants can also be used as an alternative to warfarin therapy. For those patients with a contraindication to anticoagulation therapy, an inferior vena cava filter can be considered.

Because of the significant morbidity and mortality associated with thromboembolic disease, prevention is critical, especially in the surgical patient. Radical pelvic surgery is considered to be a serious risk factor for postoperative DVT; it is associated with a DVT rate of approximately 30% and PE rate of 10% in patients without prophylaxis.[74] With prophylaxis, these rates decrease to 10% and 1.5%, respectively.

The American Urological Association in 2009 published best practice statements for the prevention of deep vein thrombosis in patients undergoing urologic surgery, which stratifies patients based on individual risk factors and takes into consideration the risk of the procedure (Table 4.10).

A topic of concern involves late thromboembolic complications. In the past, it was believed that DVT occurred in the first 3 postoperative days and that prophylaxis was indicated during that period. More recent studies, however, suggested that significant numbers of DVT and PE cases occur after hospital discharge. Huber and associates[100] determined that ≤25% of DVT and 16% of PE occurred after hospital discharge. This finding of late DVT has been noted in urologic patients as well. In a series reviewing postoperative complications in patients undergoing radical retropubic prostatectomy, investigators noted that DVT was diagnosed an average of 12 days postoperatively.[101] Late thromboembolism is thought to result from a prolonged hypercoagulable state that extends beyond the period of prophylaxis. Such prolonged states may be of particular concern in patients enduring prolonged bed rest or with concurrent malignant disease. Unfortunately, the trend toward minimally invasive surgical procedures and earlier hospital discharge may make addressing this question more difficult.

Conclusion

A practicing urologist must have a thorough understanding of hematologic complications to ensure safe and efficacious perioperative care. As urologic surgeons work with an increasingly aging population they will encounter more patients on a continually expanding list of anticoagulation medication. The risk of hemorrhage and thrombosis must be carefully weighed and decision making must occur as part of a multidisciplinary team. Patients who undergo urologic surgery are at high risk for complications that can lead to severe morbidity and mortality. The surgeon must focus on risk reduction and proper management of complications to provide excellent care.

References

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Chapter 4 Questions

1. A patient is found to have an isolated elevated bleeding time in preoperative workup. Bleeding time can be used to assess what disorder?
   a. Platelet dysfunction
   b. von Willebrand's disease
   c. Hemophilia
   d. Thrombocytopenic purpura
   e. Christmas disease

2. A male patient is treated with 7 days of ciprofloxacin for a symptomatic urinary tract infection. The patient develops anemia and jaundice with concern for hemolytic anemia. Commonly used antibiotics in urology, such as nitrofurantoin, sulfa compounds, and quinolones, can produce hemolytic anemia in patients with what condition?
   a. Lactate dehydrogenase deficiency
   b. Glucose-6-phosphate dehydrogenase deficiency
   c. Human immunodeficiency virus
   d. Lactose intolerance
   e. Leukemia

3. A 55-year-old man with coronary artery disease underwent percutaneous coronary intervention and placement of a drug eluting stent. What is the minimum time the patient should wait to be scheduled for an elective urologic procedure?
   a. 3 months
   b. 6 months
   c. 12 months
   d. 24 months
   e. 36 months

4. By how much does 1 unit of platelets raise the platelet count?
   a. 5000 to 10,000/mm^3
   b. 10,000 to 20,000/mm^3
   c. 20,000 to 50,000/mm^3
   d. 50,000 to 100,000/mm^3
   e. >100,000/mm^3

5. During preoperative history and physical exam a patient reports a family disorder of bleeding problems. What is the treatment for the most common hereditary coagulopathy?
   a. Factor VIII replacement
   b. Factor frozen plasma
   c. Fresh frozen plasma + DDAVP
   d. Cryoprecipitate + DDAVP
   e. Fresh frozen plasma + cryoprecipitate

6. A 68-year-old male patient is in your office to be scheduled for a transurethral resection of the prostate. This patient has no significant cardiac history and takes 81 mg of aspirin daily for prophylaxis. What is the mechanism of action and duration of action of this medication?
   a. Irreversible inhibition of receptor $P2Y_{12}$ for 7–10 days
   b. Reversible inhibition of receptor $P2Y_{12}$ for 3–5 days
   c. Irreversible inhibition of $P2Y_{12}$ for 3–5 days
   d. Irreversible inhibition of cyclooxygenase 1 for 7–10 days
   e. Reversible inhibition of cyclooxygenase 1 for 3–5 days

7. An 80-year-old male with a history of atrial fibrillation and chronic kidney disease is undergoing a suprapubic prostectomy. During the procedure significant hemorrhage is encountered that is difficult to control. The anesthesiologist reviews the record and confirms that the patient stopped his dabigatran 2 day prior to the surgery as instructed by his cardiologist. What blood products should be ordered in this situation?
   a. Packed red blood cells with fresh frozen plasma and platelets as needed
   b. Fresh frozen plasma
   c. Platelets
   d. Cryoprecipitate
   e. Protamine sulfate

8. A male patient is admitted with acute renal failure and gross hematuria refractory to conservative management. Coagulation labs are sent and the results are reviewed. PT 12 (normal 11–13.5 seconds), PTT 28 (normal 25–35 seconds), Hgb 11 g/dL (normal 13–18 g/dL). What is the defect leading to a coagulopathy in this uremic patient?
   a. Red blood cell problems
   b. Heparin-induced thrombocytopenia
   c. Platelet dysfunction
   d. Dilutional coagulopathy
   e. Disseminated intravascular coagulopathy

9. Virchow's triad for formation of thrombus includes stasis and hypercoagulability. What is the third characteristic?
   a. History of deep venous thrombosis
   b. Smoking history
   c. Malignancy
   d. Obesity
   e. Blood vessel injury

10. A 65-year-old male undergoes radical prostatectomy. On postoperative day 2 the patient is found to have heart rate of 110, oxygen saturation dropped to 90–92%, and right lower extremity swelling. The patient's postoperative creatinine is 2, which is at his preoperative baseline. What is the best initial test for a suspected pulmonary embolus in this patient?
    a. Chest CT scan with IV contrast
    b. Ventilation/perfusion lung scan
    c. Magnetic resonance imaging (MRI) of the chest
    d. Doppler study of the lower extremity
    e. Echocardiogram

Case Studies

CASE 1

A 55-year-old man with rate-controlled atrial fibrillation is anticoagulated with rivaroxaban (Xarelto). The patient is

scheduled to undergo a transurethral resection of a bladder tumor. After consultation with his primary care physician and cardiologist, the decision was made to stop the anticoagulation prior to the procedure due to risk of hemorrhage.

1. How long prior to the procedure should a novel oral anticoagulant be stopped?
   a. >14 days
   b. >7 days
   c. >2 days
   d. 1–2 days
   e. <8 hours

2. What are the available reversal agents for apixiban (Eliquis)?
   a. Vitamin K
   b. Fresh frozen plasma
   c. Protamine
   d. Dialysis
   e. None

3. What laboratory value is used routinely to monitor anticoagulation with the novel oral anticoagulant medications?
   a. INR (international normalized ratio)
   b. None
   c. Bleeding time
   d. aPTT (activated partial thromboplastin time)
   e. Anti-Xa assay

CASE 2

A 36-year-old male was found to have a testicular mass on scrotal ultrasound and is scheduled for a radical inguinal orchiectomy. The patient was found to have von Willebrand's disease after prolonged bleeding during a dental procedure as a child.

1. What is the primary defect in von Willebrand's disease?
   a. Inability to convert prothrombin to thrombin
   b. Lack of functional clotting factor IX
   c. Low plasma fibrinogen
   d. Dysfunction in platelet adhesion
   e. Inhibition of cyclooxygenase

2. After consultation with the patient's hematologist, the patient underwent preoperative transfusion with cryoprecipitate to lower the risk of bleeding. What other intervention could be used to treat this patient's coagulopathy?
   a. Protamine
   b. Aminocaproic acid
   c. Desmopressin (DDAVP)
   d. Dialysis
   e. Red blood cell transfusion

3. The patient is consented for blood transfusion preoperatively. What is the most common viral infection transmitted with contemporary blood transfusion?
   a. Hepatitis C
   b. Hepatitis B
   c. Human immunodeficiency virus
   d. Cytomegalovirus
   e. Human T-lymphotropic virus (HTLV)

Answers

1. **a.** The prothrombin time (PT) measures the activity of the extrinsic clotting system, and the activated partial thromboplastin time (aPTT) measures the intrinsic clotting system. Measurement of the bleeding time is used to identify patients in whom platelet function defects may exist.
2. **b.** Commonly used antibiotics in urology, such as nitrofurantoin, sulfa compounds, and quinolones, can produce hemolytic anemia in patients with glucose-6-phosphate dehydrogenase deficiency. Hemolytic anemia has also been associated with renal cell carcinoma and seminoma.
3. **c.** Elective noncardiac surgery should be delayed 14 days after PCI with balloon angioplasty (no stent placement), 30 days for bare metal stent implantation, and 365 days after placement of a drug eluting stent. Elective noncardiac surgery can be considered after 180 days if the risk of surgical delay is greater than the risk of ischemia or stent thrombosis.
4. **a.** Although a normal platelet count can vary greatly among patients, a count of more than 50,000 platelets/mm^3 is usually adequate for surgical hemostasis. One unit of platelets can be expected to raise the platelet count by 5,000 to 10,000/mm^3.
5. **d.** The most common hereditary disorder is von Willebrand's disease. Symptoms are usually manifested in late childhood and most commonly include easy bruising and bleeding at skin sites or mucus membranes. Treatment is preferably with cryoprecipitate and desmopressin (DDAVP), which induces endothelial release of VWF and coagulation factor VIII.
6. **d.** Acquired intrinsic platelet dysfunction occurs with the use of aspirin, clopidogrel, and nonsteroidal anti-inflammatory drugs (NSAIDs). Aspirin irreversibly inhibits the enzyme cyclooxygenase 1 (COX-1). The platelet life span is approximately 7–10 days, and platelet function typically resumes 7–10 days after the last use of these medications.
7. **a.** Normally the novel oral anticoagulants should be discontinued >48 hours prior to a procedure but a longer interval of discontinuation should be used in the setting of renal impairment. There are no current antidotes or reversal agents for these medications. A patient who is experiencing severe hemorrhage while taking a novel oral anticoagulant should be managed with fluid resuscitation and repletion of blood products by transfusion as needed.
8. **c.** Renal disease can be associated with functional defects in red blood cells, platelets, leukocytes, and coagulation factors. Significant bleeding conditions can occur in the uremic patient, most commonly due to impaired platelet function.
9. **a.** The classic risk factors for venous thrombosis are stasis, hypercoagulability, and intimal injury (i.e., Virchow's triad). Other risk factors include advanced

age (>60 years), obesity, history of deep venous thrombosis, prolonged immobility, pregnancy, malignancy, fracture, estrogen use, and major medical conditions leading to venous stasis.

10. **b.** If the index of suspicion is high and particularly for those in the postoperative period, spiral computed tomography (CT) is warranted and considered by most to be the standard initial diagnostic test. In patients with existing renal dysfunction for whom IV contrast dyes cannot be given, the best initial assessment for pulmonary embolus is a ventilation/perfusion scan.

CASE 1

1. **c.** The novel oral anticoagulants should be stopped at least 48 hours prior to a scheduled procedure. A longer interval of discontinuation should be used in the setting of renal impairment.
2. **e.** There are currently no available reversal agents for the novel oral anticoagulants.
3. **b.** The novel oral anticoagulants are commonly administered without routine monitoring. Qualitative assessment of anticoagulation can be performed with prothrombin time for factor Xa inhibitors (rivaroxaban [Xarelto], apixaban [Eliquis]) and activated partial thromboplastin time for direct thrombin inhibitors (dabigatran etexilate [Pradaxa]). Apixiban has a limited effect on PT, and anti-factor Xa assays can be used to determine the anticoagulant activity.

CASE 2

1. **d.** von Willebrand's factor is a plasma protein that mediates platelet adhesion and binds to and stabilizes coagulation factor VIII in the circulation.
2. **c.** Desmopressin induces endothelial release of VWF and coagulation factor VIII.
3. **b.** The rate of hepatitis transmission is 1 in 220,000. The most common transfusion reactions are febrile nonhemolytic and allergic.

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5 Metabolic Complications of Urologic Surgery

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CHAPTER OUTLINE

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Stomach
Jejunum
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Altered Sensorium
Chapter 5 Questions and Answers

KEY POINTS

1. Unless the patient is severely symptomatic, correction of hyponatremia should proceed slowly so as to avoid the development of central pontine myelinolysis.
2. The mechanism of transurethral resection (TUR) syndrome likely involves a combination of hyponatremia, hyperammonemia, and/or hyperglycinemia. Fluid resuscitation, possibly with hypertonic saline (3% NaCl), is appropriate.
3. Brisk diuresis (>200 mL/hr) following the relief of urinary obstruction constitutes postobstructive diuresis (POD). Patients with POD should be monitored and treated to ensure that volume depletion and electrolyte disturbance do not occur. Most often, however, the diuresis is physiologic and will cease spontaneously without significant sequelae.
4. The frequency and severity of metabolic complications following urinary diversion depend on the segment of bowel used, surface area, contact time, urine composition, renal function, and liver function. Severe metabolic disturbance is most common with the use of jejunum. This segment should only be used if ileum or colon is either unavailable or inadvisable. Complications with continent urinary diversion can be minimized if this form of diversion is limited to patients with a serum creatinine <2.0 mg/dL and a normal urine protein concentration.

Perioperative Management of the Patient With Chronic Kidney Disease

In the United States, the prevalence of chronic kidney disease (CKD) is estimated to be 13% of adults over the age of 20 years and the lifetime risk of developing CKD is >50% for adults living more than 65 years.[1,2] It is associated with numerous complications and comorbid conditions that together pose a definite morbidity and mortality risk. Fortunately, adverse outcomes from renal insufficiency can be delayed or prevented through appropriate monitoring and early treatment. As such, it is essential that urologists maintain a basic understanding of CKD, particularly as it applies to perioperative management.

DEFINITION OF CHRONIC KIDNEY DISEASE

In 2002 the Kidney Disease Outcome Quality Initiative (K/DOQI) defined CKD according to the presence of objective renal damage (e.g., proteinuria >300 mg/day) or a glomerular filtration rate (GFR) below 60 mL/min/1.73 m^2 for >3 months.[2] GFR, the best measure of overall renal function, represents the product of the number of functioning nephrons and single-nephron GFR. GFR can be estimated using the Cockcroft-Gault equation for creatinine clearance. Normal reference levels of GFR vary with age, gender, and body size. A GFR of 60 mL/min/1.73 m^2 represents roughly half the normal adult GFR. The K/DOQI definition allows for the normal age-related decline in GFR (~1 mL/min/1.73 m^2 per year) that occurs after the age of 20 or 30 years.[2]

MANAGEMENT OF COMORBIDITIES AND COMPLICATIONS

The numerous complications and comorbid conditions associated with CKD may negatively impact patient outcomes independent of the renal dysfunction itself. Each deserves individual consideration and management so as to minimize the potential for adverse events in the perioperative period.

Diabetes mellitus and hypertension represent the leading causes of end-stage renal disease (ESRD).[3,4] New-onset or worsening hypertension, secondary to hypervolemia and stimulation of the renin angiotensin system, also represents a common complication of CKD.[5] Strict glycemic control and optimization of blood pressure are obvious goals in the perioperative period. Angiotensin-converting enzyme (ACE) inhibitors and angiotensin-receptor blockers (ARBs) are first-line antihypertensive agents used in this setting; their use is based on studies that demonstrate effective blood pressure control and reduced risk of progression to ESRD in both diabetic and nondiabetic CKD patients.[6,7] Diuretics, followed by calcium channel or beta-blocking agents, may be added if blood pressure remains high despite ACE inhibitors or ARBs.[8] Loop diuretics are preferred over thiazides if the GFR is <30 mL/min/1.73 m^2.[9]

Cardiovascular disease is a common complication of CKD. Relative to the general population, the cardiovascular risk is threefold higher among patients with mild renal insufficiency and 65-fold higher in patients with ESRD.[10,11] Reasons for this include extraskeletal calcification (e.g., valvular, atherosclerosis) secondary to calcium-phosphorous dysregulation, ventricular hypertrophy secondary to chronic anemia, and congestive heart failure (CHF) exacerbated by hypervolemia, as well as hypertension, diabetes, and dyslipidemia.[12] Patients with longstanding CKD or a history of myocardial ischemia warrant preoperative cardiac evaluation, particularly if invasive surgery is planned.

Anemia is common in patients with a GFR <60 mL/min/1.73 m^2.[13] It is typically normochromic normocytic and reflects insufficient production of erythropoietin. Most patients with CKD are symptomatic (e.g., fatigue) at hemoglobin values <11 g/dL. Chronic anemia may promote left ventricular hypertrophy, CHF, and myocardial ischemia if untreated.[12] Supplemental iron and vitamins are usually ineffective, and repeated transfusion risks the development of immune sensitization, which may compromise future transplantation. Recombinant erythropoietin is recommended as primary treatment. Maintaining the serum hematocrit at 33% to 36% or hemoglobin at 11 to 12 g/dL has been shown to reduce cardiovascular mortality by 30%.[14,15]

Patients with renal insufficiency may develop a bleeding diathesis late in the course of disease as demonstrated by a prolongation in bleeding time. The primary defect involves an abnormality in von Willebrand's factor (vWF)-related platelet aggregation and platelet–vessel wall interaction. Measures to correct this include administration of cryoprecipitate, factor III, or DDAVP (1-deamino-8-D-arginine vasopressin), all of which raise circulating levels of vWF. Correction of anemia with either erythropoietin or red blood cell transfusion also may improve the bleeding profile. These strategies are recommended as both prophylaxis and treatment in uremic patients undergoing major surgery.

FLUID AND ELECTROLYTE CONSIDERATIONS

Most patients with CKD are able to maintain fluid and electrolyte homeostasis until the renal function decreases to a GFR of 15 mL/min/1.73 m^2.[16,17] Homeostasis occurs because an adaptive increase in both single nephron GFR and tubular function causes an increase in the fractional excretion of water and electrolytes. Such adaptation can only maintain homeostasis under the conditions of a normal diet, however. Extreme changes in diet, as may occur perioperatively, often lead to fluid and electrolyte imbalance.

Patients with CKD progressively lose the ability to both conserve and excrete sodium. When the GFR falls below 15 mL/min/1.73 m^2, sodium excretion becomes relatively fixed and the kidneys are no longer able to compensate for changes in sodium intake and nonrenal sodium loss.[18] At a GFR of 5 mL/min/1.73 m^2, the excretion of 120 to 140 mEq of sodium per day allows for a daily sodium intake of 5 to 10 g. Dietary intake below 2 g per day risks sodium depletion, whereas intake above 10 g risks total body sodium excess. Sodium depletion secondary to nonrenal loss is not uncommon in the perioperative period. Risk factors for sodium depletion include nasogastric suction, vomiting, diarrhea, and fistula drainage. Perioperative diuretic therapy may worsen the situation by augmenting renal sodium excretion. Patients without risk factors for sodium depletion require 5 to 10 g of sodium per day (diet or

intravenous [IV]) to maintain homeostasis, whereas those with established risk factors require additional supplementation. In the setting of severe peripheral (or pulmonary) edema or hypertension, sodium intake should be limited to 2 g per day in order to avoid further fluid overload.

As renal failure progresses, the kidneys also lose the ability to concentrate and dilute urine. The concentration defect results from an impairment in the medullary solute gradient, which often overshadows the dilution defect until renal failure is quite advanced. Typically, water loads are well tolerated until the GFR approaches 15 mL/min/1.73 m^2.[16,17] In conjunction with the inability to regulate sodium excretion, the concentration defect predisposes patients with CKD to dehydration. The solute load generated by the intake of 5 to 10 g of sodium per day results in an obligate urine volume of 1.5 to 2.0 L.[18] Consideration of perioperative fluid replacement must take into account obligate urine output in addition to the customary loss that occurs through hemorrhage, drainage, or insensible routes. Failure to do so may result in severe dehydration and an acute worsening of renal function through inadequate renal perfusion (pre-renal failure). Fluid intake should be maintained at a minimum of 1.5 L per day unless the patient has ESRD, in which case intake should match urine output plus insensible losses.

Hyponatremia is common in patients with severe CKD due to the impaired excretion of free water (i.e., dilution defect). Fluid restriction to less than 1 L per day is generally sufficient.

Hyperkalemia is uncommon in CKD until the GFR falls below 25% of normal. Patients with severe CKD are unable to fully excrete the daily potassium load; thus they are exquisitely sensitive to changes in intake. Exogenous intake of potassium, be it through diet or medications, is the most common cause of hyperkalemia in CKD. As such, potassium restriction is an important component of therapy.

PREOPERATIVE EVALUATION

Patients with CKD require a careful preoperative determination of overall health. The basic evaluation includes a careful history and physical examination, complete metabolic profile, coagulation times, electrocardiogram, and plain radiograph of the chest. The presence of comorbid or complicating conditions should be determined preoperatively and managed accordingly. A detailed list of prescribed medications should be made because polypharmacy is common. Medications that adversely affect renal function or whose clearance depends on adequate renal function may require substitution or a reduction in dose. Nephrology consultation is advised for both perioperative and long-term care if the GFR is below 30 mL/min/1.73 m^2.

Hyponatermia

Hyponatremia is the most common electrolyte disturbance encountered in clinical practice.[19] Mild hyponatremia defined as a serum sodium of 130–135 mEq/L is seen in nearly 30% of admitted patients while moderate to severe hyponatremia (<125-129 mEq.L) is seen in up to 7% of patients.[20]

ETIOLOGY

Hyponatremia may be due to loss of total body sodium, dilution of sodium in serum, or a false lab test.[19,21] True hyponatremia consists of a dilution of sodium by water leading to a decreased serum concentration of sodium. This results in a hypo-osmolar serum (<280 mOsm/kg water). Sodium may also be diluted due to elevated levels of glucose or mannitol. As glucose levels rise, water is drawn into the extracellular space by osmosis thereby diluting sodium without changing total body water (TBW) or total body sodium. The patient's serum is hyperosmolar (>295 mOsm/kg water). A correction factor of 2.4 mEq/L of sodium per 100 mg/dL of glucose over 100 mg/dL can be used to correct for this dilution.[21,22] Patients with hyponatremia but a normal serum osmolality (280 and 295 mOsm/kg water) have pseudohyponatremia. Normally, water and electrolytes account for 93% of serum volume, while fat and protein account for the other 7%. If a patient develops hyperlipidemia or hyperproteinemia to the point that water accounts for <80% of the serum volume, the concentration of sodium is under estimated. This occurs because standard lab equipment reports a value based on liter of serum not liter of water assuming that the serum is made up of 93% water.[23] The machine samples the same volume of fluid but the increased lipids or protein means that less water and sodium is taken up so the concentration is underestimated.

True hyponatremia is organized into subcategories based on the patient's fluid status: hypovolemic, euvolemic, and hypervolemic states. These can be further delineated based on urine sodium concentration (U_{Na}).[24] See Table 5.1 for common etiologies of hyponatremia based on fluid status and urine sodium concentration.

PRESENTATION

Mild hyponatremia is commonly asymptomatic. Moderate or severe hyponatremia can present with headaches, nausea, vomiting, muscle cramps, lethargy, seizures, and coma secondary to cerebral edema.[21,24,25] To prevent excess swelling, the brain adjusts intracellular solutes to accommodate for serum electrolyte changes.[19] In acute settings, cells do not have time to adapt so the swelling and symptoms are more pronounced. When onset of hyponatremia is slow, the brain is able to adapt to prevent swelling and minimize central nervous system symptoms.[19]

MANAGEMENT

Management of hyponatremia is based on the acuity of onset and severity of symptoms. Rapid correction of hyponatremia can result in osmotic demyelination syndrome (ODS), previously called central pontine myelinolysis.[24] This devastating neurologic complication is usually reported in the context of chronic hyponatremia; however, it also may occur following the overly rapid correction of acute hyponatremia. Unless the patient is severely symptomatic, correction of hyponatremia should proceed slowly to avoid ODS.

For patients with acute onset, severely symptomatic hyponatremia, a 100 mL bolus of 3% NaCl over 10 minutes

Table 5.1 Etiology of True Hyponatremia

Urinary Sodium Concentration	Hypervolemic States	Euvolemic States	Hypovolemic States
Urine sodium >20 mEq/l	Renal failure	Addison's disease (glucocorticoid) SIADH	Jejunal conduit Diuretic overuse Renal salt wasting (RTA) Nephrogenic diabetes insipidus Mineralocorticoid insufficiency
Urine sodium <20 mEq/l	Congestive heart failure Hypoalbuminemia (cirrhosis, nephrotic syndrome)	Psychogenic diabetes insipidus	Excessive fluid losses (GI losses, heat stroke)

GI, gastrointestinal; RTA, renal tubular acidosis; SIADH, syndrome of inappropriate antidiuretic hormone secretion

Table 5.2 Management of Acute (48 Hours) or Symptomatic Hyponatremia

Treatment Level	Indication	Sodium Solution	Dosage	Duration
1	Asymptomatic plus serum Na >120 mEq/L	0.9% NaCl	Based on Na^+ deficit	Until serum Na normal
2	Serum Na <120 mEq/L or symptomatic	3% NaCl	1–2 mL/kg/hr	Until symptoms improve
3	Severe symptoms	3% NaCl	4–5 mL/kg/hr	1–2 hr

Notes
Administer hypertonic saline via central venous catheter is preferred route for continuous replacement
If furosemide is added, it may double the rate of SNa rise
Measure SNa q 1–2 hours in early stages
Regress through levels of treatment as SNa and symptoms improve

Na, sodium; NaCl, sodium chloride; SNa, serum sodium concentration
(Adapted from Decaux G, Soupart A. Treatment of symptomatic hyponatremia. Am J Med Sci. 2003;326(1):25-30.)

may be used up to three times until symptoms subside.[21] The sodium load of 100 mL of 3% Na is equal to 51 mEq Na. For milder acute cases, infusions of 3% NaCl at 0.5–2 mL/kg/hr may be used. Central venous access is recommended for the administration of continuous hypertonic saline; however, in emergency situations 3% NaCl can be given through a large bore peripheral IV without risk of a limb- or life-threatening event.[26]

For patients with chronic hyponatremia, the management is based on a slower controlled rate of correction. In asymptomatic mild hyponatremia, the first line of treatment is fluid restriction.[24] If this is ineffective, salt tabs or loop diuretics may be added. In mildly symptomatic hyponatremia, serum Na should be corrected at a rate of 1 mEq/L/hr.[21,25] The 24 hour goal is to increase serum Na by at least 4–8 mEq/day but to not exceed 10–12 mEq/L in any 24-hour period. Additionally, an increase in Na greater than 18 mEq/L in any 48-hour period should be avoided.[25] In contrast, patients with chronic hyponatremia and severe neurologic symptoms (e.g., seizures, coma) require rapid correction to a serum sodium level of 120 mEq/L over 1 to 2 hours, or until symptoms regress.

Guidelines for hypertonic saline administration are provided in Table 5.2. Calculation of the sodium deficit may serve to guide replacement. Serum electrolytes (sodium) should be monitored frequently to guide treatment every 1 to 2 hours, initially.

Syndrome of Inappropriate Antidiuretic Hormone Secretion

ETIOLOGY

Syndrome of inappropriate antidiuretic hormone secretion (SIADH) is a euvolemic form of hyponatremia due to excess antidiuretic hormone (ADH), also called vasopressin. In normal physiology, endogenous vasopressin is released from the posterior pituitary in response to increasing serum osmolality to increase free water absorption. In pathologic states, abundant release of vasopressin may be the response to CNS disturbances (stroke, trauma, infection), drugs (antiepileptics, chemotherapeutics, antipsychotics, opioids, Ecstasy), pulmonary disease (asthma, pneumonia, atelectasis), and hormone deficiencies (hypothyroidism, hypopituitarism). Extra-pituitary sources of vasopressin that may also cause SIADH include malignancies producing ADH (small cell carcinoma [SCC] of the lung, extrapulmonary SCC, head and neck cancer, olfactory neuroblastoma) or drug administration of vasopressin, desmopressin, or oxytocin.[21,27]

MECHANISM

Vasopressin activates V_2 receptors in the collecting duct of the kidney to increase free water uptake.[21] Activated V_2

Box 5.1 Bartter and Schwartz 1967 Criteria for SIADH

- Hyponatremia (Na <135 mEq/L)
- Clinically euvolemic
- Elevated urinary sodium excretion (U_{Na} >20 mmol/L)
- True plasma hypo-osmolality (P_{osm} <275 mOsm/kg H_2O)
- Inappropriate urinary concentration (U_{osm} >100 mOsm/kg H_2O)
- Normal renal function and absence of diuretic use
- Normal salt and water intake
- Absence of other etiologies of euvolemic hypo-osmolality: hypothyroidism, glucocorticoid deficiency

Na, serum sodium concentration; U_{Na}, urine sodium concentration; P_{osm}, plasma osmolality; U_{osm}, urine osmolality

(Adapted from Verbalis JG, Goldsmith SR, Greenberg A, Korzelius C, Schrier RW, Sterns RH, et al. Diagnosis, evaluation, and treatment of hyponatremia: expert panel recommendations. Am J Med. 2013;126(10 Suppl 1):S1-S42.)

increases cAMP via adenyl cyclase, which causes the transportation of intracellular vesicles containing aquaporin-2 to the apical plasma membrane along with up-regulation of aquaporin-2 synthesis.[28,29] Aquaporins allow water reabsorption through the plasma membrane of the collecting duct. Total body sodium stays the same but TBW is increased, resulting in hyponatremia.[28]

PRESENTATION

SIADH presents similarly to other forms of hyponatremia ranging from asymptomatic to seizure and coma; however, it is important to note that these patients will be clinically euvolemic.

EVALUATION

In 1967 Bartter and Schwartz developed the criteria for diagnosis of SIADH which is still used today.[25] These are listed in Box 5.1.

MANAGEMENT

The management algorithm of SIADH, as with other hyponatremia patients, is based on acuity and severity. For most patients this is a chronic problem requiring slow correction. Asymptomatic patients are initially treated with restriction of fluids, not just free water. Thirsty patients may be offered hard candy or very small volumes of ice chips. Loop diuretics, not thiazides, may be added. Severely symptomatic patients may require hypertonic saline prior to other therapies.

Vasopressin receptor antagonists (vaptans) can be used as adjuvant treatment for SIADH. They prevent excess activation of V_2 receptors by competitively blocking the binding site of vasopressin.[20] This results in diuresis even in the presence of excess vasopressin. Currently in the United States, the only two V_2 antagonists available are conivaptan (IV) and tolvaptan (oral). Both should be started in the inpatient setting, and use is at the discretion of the prescribing physician. These medications are not recommended as a single agent therapy but rather in combination with fluid restriction and sodium replacement.[20]

Transurethral Resection Syndrome

ETIOLOGY

TUR syndrome is a constellation of signs and symptoms caused by the intravascular absorption of hypotonic fluids during endoscopic surgery. It is most commonly reported following transurethral resection of the prostate (TURP), but it may complicate any endoscopic procedure in which hypotonic irrigation is used,[30] including cystoscopy, bladder tumor resection, percutaneous nephrolithotripsy, and transcervical endometrial resection. Intravascular absorption of irrigant occurs primarily through direct infusion into open venous channels; however, reabsorption of extravasated fluid following inadvertent perforation of the prostatic capsule or bladder wall also may occur. This distinction is important because TUR syndrome secondary to direct intravascular absorption presents acutely, whereas TUR syndrome associated with extravasation may be delayed up to 24 hours.[31]

Early reports of TUR syndrome noted reddish discoloration of the serum, progressive oliguria, azotemia, pulmonary edema, and even death following the absorption of large amounts of sterile water during TURP. In initial reports of TUR syndrome, rapid water absorption resulted in severe hemolysis and the resulting sequelae. Nonelectrolyte solutions were subsequently utilized with osmolalities similar to serum (275–290 mOsm/kg H_2O). These solutions included glycine, mannitol, and sorbitol. Although the risk of hemolysis with such solutions is negligible, TUR syndrome remains a concern, albeit less common, because while using monopolar electrocautery, modern irrigants are hypo-osmolar relative to serum (1.5% glycine = 200 mOsm/kg). The incidence of TUR syndrome among patients undergoing TURP with glycine is 1% to 10%.[30] Mortality ranges from 0.2% to 0.8%.[31]

In recent years, alternatives to monopolar TURP have become increasingly popular for the management of benign prostatic hyperplasia (BPH). These include bipolar electrocautery, green light vaporization, and holmium laser enucleation of the prostate. Standard TURP uses monopolar electrocautery, which requires a nonionic fluid to prevent conduction though the irrigant. Alternatively, newer methods utilize normal saline as they do not require electrical conduction through the patient to work. While fluid overload from absorption of fluid is possible, TUR syndrome has not been reported postoperatively in patients undergoing these procedures.[32–34]

MECHANISM

The mechanism of TUR syndrome is not universally agreed upon. Leading theories include the following:[30,35]

1. Intravascular fluid absorption
2. Hyponatremia

3. Hyperammonemia
4. Hyperglycinemia.

Although hyponatremia is the primary cause of TUR syndrome, multiple factors may be responsible resulting in a heterogeneous presentation.

It is estimated that 20 mL of irrigation fluid is absorbed per minute of resection during TURP.[36] Rapid or prolonged intravascular absorption causes a transient hypervolemia as demonstrated by an initial rise in central venous pressure (CVP), which plateaus within 15 minutes.[30,36] Hypertension and reflex bradycardia are common early; however, as the syndrome progresses, a hypokinetic hemodynamic phase characterized by hypotension and bradycardia often develops. This hemodynamic shift reflects a decline in both cardiac output and intravascular volume, which begin once irrigation is discontinued.[30,37,38] Factors responsible include natriuresis, osmotic diuresis, intracellular uptake of water, hyponatremia, hypocalcemia, and hypothermia among others.

Hyponatremia results from (1) expansion of the extracellular compartment by the infusion of hypotonic fluid (i.e., dilutional hyponatremia), and (2) increase in the urinary excretion of sodium (i.e., natriuresis). The relative contribution of dilution and natriuresis toward hyponatremia depends on the amount of irrigation absorbed and the timing of serum sodium analysis.[39] Early in the course of absorption, sodium dilution predominates because the majority of fluid remains extracellular. As the osmotic gradient widens, water is progressively drawn into the intracellular space such that hyponatremia reaches its nadir when hypotonic irrigation is stopped. Less than 50% of the absorbed fluid remains extracellularly 30 minutes after infusion has ended.

Serum sodium is commonly used to quantify extracellular fluid (ECF) volume expansion; however, it is only at the completion of surgery that such an estimate is accurate. The degree of hyponatremia is an inaccurate measure of extracellular hydration at all other points in the postoperative period. Cases of irrigant extravasation represent an exception to this rule because hyponatremia in this setting is most pronounced 2 to 4 hours after surgery due to delayed reabsorption. The systemic absorption of glycine also stimulates renal sodium excretion.[30]

Severe acute hyponatremia secondary to TUR syndrome presents similarly to other forms of acute hyponatremia. Cerebral edema leads to nausea, vomiting, confusion, and even seizures and coma if not treated promptly. Hypertension and bradycardia (i.e., Cushing reflex) also may arise as a consequence of heightened intracranial pressure. Radiologic studies demonstrate that cerebral edema may occur following the absorption of as little as 1 L of hypotonic irrigation.[40] By comparison, irrigation with normal saline causes a greater expansion of the intravascular space, but cerebral edema is uncommon.[30]

The most common irrigant used during TURP today is 1.5% glycine. Independent of volume and electrolyte imbalance, glycine and its metabolites retain properties that directly contribute to TUR syndrome in a dose-dependent manner.[27,28] Glycine is metabolized by the liver into ammonia and glyoxylic acid. A small proportion (10%) is excreted unchanged by the kidneys and promotes an osmotic diuresis and natriuresis.[30] Within the retina and central nervous system, glycine functions as an inhibitory neurotransmitter. Visual disturbance is reported in 10% of patients absorbing more than 500 mL of 1.5% glycine solution.[30,41,42] With continued absorption, this may progress to transient blindness, which generally resolves within 24 hours and requires no specific treatment.[43] Depending on the volume of glycine absorbed, a spectrum of mental status changes may be noted. The spectrum includes confusion, depressed consciousness, and coma. Glycine also impairs cardiac conduction and contractility through the generation of subendocardial hypoxic lesions.[44]

Ammonia represents an intermediate product in the hepatic metabolism of glycine. Normally, ammonia is further metabolized by the liver into urea, which is then excreted by the kidneys. In cases of renal or hepatic insufficiency, however, the metabolism of ammonia is impaired and hyperammonemic encephalopathy may occur. Serum ammonia levels tend to correlate with the incidence and severity of neurologic symptoms.[45] Hyperammonemic encephalopathy secondary to glycine absorption is self-limited and will gradually correct once the infusion is stopped. Only supportive measures need be provided.

RISK FACTORS

Potential risk factors for the development of TUR syndrome are listed in Box 5.2.[30] Although the extent of resection correlates with the volume of irrigation absorbed and the incidence of TUR syndrome, the relationship between TUR syndrome and irrigation pressure is not as precise. Two large studies have failed to demonstrate any correlation between bag height and fluid absorption during TURP.[46,47] Smoking has been shown to be an independent predictor of large-scale fluid absorption (>1 L) in patients undergoing TURP. This is thought to reflect an increase in prostatic micro-vessel density among smokers.[48]

PRESENTATION

The presentation of TUR syndrome is heterogeneous and depends on the volume, rate, route, and type of fluid absorbed. Mild cases usually present 30 to 45 minutes after the completion of surgery and may be overlooked.[30] Symptoms are usually neurologic or cardiovascular in origin

Box 5.2 Risk Factors for Transurethral Resection Syndrome During Transurethral Resection of the Prostate

- Extensive resection
- >45 grams
- >90 minutes
- Open venous sinus
- Capsular perforation
- High pressure irrigation
- >40 cm H_2O
- Intermittent flow resection
- Smoking history

(Data from Hahn RG. Fluid absorption during endoscopic surgery. Br J Anaesth. 2006;96(1):8–20.)

Table 5.3 Symptoms of Transurethral Resection Syndrome

Cardiovascular	Neurologic
Bradycardia	Nausea
Hypertension	Vomiting
Hypotension	Restlessness
Shortness of breath	Confusion
Chest pain	Depressed consciousness Headache Blurred vision Blindness

(Table 5.3). During the intraoperative and early postoperative period, nausea, vomiting, restlessness, confusion, and visual disturbance are common as are the sensations of facial prickling and warmth. Blindness, seizures, and coma may occur in extreme cases. Although transient hypertension and bradycardia can be seen initially, hypotension secondary to gradual ECF volume contraction is more common and problematic. Pulmonary edema may develop in patients with left ventricular dysfunction. In the event of extravasation, abdominal pain radiating to the shoulder is common.

EVALUATION

Suspicion of TUR syndrome intraoperatively warrants prompt termination of the procedure after hemostasis is attained. Serum sodium and osmolality should be measured at the completion of surgery because it is only at this time that they accurately quantify ECF volume expansion. Most patients are not symptomatic until the serum sodium concentration falls to <125 mEq/dL.

Supplementary measures of fluid absorption include volumetric fluid balance (Volume irrigation − Volume recovered = Volume absorbed), patient weight, CVP, and ethanol breath measurement; however, these are not in widespread clinical use. In addition to laboratory evaluation, hemodynamic stability and intravascular volume status should be determined. This may involve central venous or pulmonary capillary wedge pressure monitoring in unstable patients.

MANAGEMENT

The treatment of TUR syndrome must address both volume status and hyponatremia. On one hand, hypertension secondary to volume overload is usually transient and will resolve spontaneously as the osmotic diuresis and intracellular transfer of fluid proceed. Cardiovascular collapse, on the other hand, requires urgent treatment. Unstable patients with profound hypotension and bradycardia are treated with atropine, epinephrine, and IV calcium.[49]

Fluid restriction and loop diuretics can be used to correct volume overload and hyponatremia; however, plasma volume expansion and sodium supplementation should be the goal. This can be achieved using IV normal saline (0.9% NaCl) in patients with mild symptoms and serum sodium >130 mEq/L or, in severe cases, hypertonic saline.[30,37] The primary indication for use of loop diuretics is acute symptomatic pulmonary edema that fails to resolve with spontaneous diuresis. The combination of hypertonic saline and furosemide may be appropriate in severe cases (e.g., seizure, obtundation, or coma) wherein rapid correction of hyponatremia is necessary.[30,50] The addition of furosemide (20–40 mg) in this manner accelerates the rise in serum sodium twofold over hypertonic saline alone.

Postobstructive Diuresis

POD refers to the dramatic urine output that may occur following the relief of bilateral ureteral obstruction (BUO) or obstruction of a solitary kidney. The true incidence of POD is not known; however, it does appear to be an uncommon event. Factors necessary for its development include an accumulation of TBW, sodium, and urea or an impairment of tubular or collecting duct reabsorptive capabilities. Most cases of POD involve chronic urinary obstruction; however, significant changes in glomerular and tubular function are evident within 24 hours of complete ureteral obstruction.[51] Although ipsilateral renal function is compromised in all cases of ureteral obstruction, clinically significant POD is uncommon in patients with a normal contralateral kidney. This reflects the continued maintenance of fluid and electrolyte homeostasis by the contralateral kidney. For the purpose of this review, only the pathophysiology of BUO (or obstruction of a solitary kidney) as it pertains to obstructive uropathy and POD is discussed.

ETIOLOGY

Urinary obstruction may be anatomic or functional (e.g., neurogenic bladder) in etiology and intrinsic or extrinsic in location. A multitude of etiologies exist, the most common of which include BPH or prostate cancer in males and cervical cancer or pregnancy in females. Although nephrolithiasis is a relatively frequent cause of acute obstruction, most cases of POD involve chronic and progressive urinary obstruction as may occur with bladder outlet obstruction (e.g., BPH) or extrinsic bilateral ureteral obstruction (e.g., cervical cancer).

PATHOPHYSIOLOGY OF OBSTRUCTIVE NEPHROPATHY

Obstructive nephropathy refers to the functional and pathologic damage sustained by the renal parenchyma during urinary obstruction. The severity and consequences thereof depend on the degree and duration of obstruction as well as the presence or absence of an unobstructed contralateral kidney. Our present understanding of the involved pathophysiology comes mainly from animal models of complete unilateral or bilateral ureteral obstruction for 24 hours or more.

Upon the initiation of complete obstruction, profound changes in renal hemodynamics and glomerular filtration take place. In the case of BUO, such changes follow a biphasic pattern.[51] Within the first 2 hours of obstruction, GFR begins to fall as a consequence of elevated tubular hydraulic pressure (P_T). Beyond this period, P_T continues to rise and,

more importantly, renal blood flow (RBF) falls dramatically as a result of intense efferent arteriolar vasoconstriction caused by angiotensin II, thromboxane A_2, and neural input.[52] Intrarenal blood flow is also preferentially directed toward the outer cortex in BUO, leaving many glomeruli nonperfused.

The end result is a profound reduction in single nephron and whole kidney GFR by 24 hours. Animal models report ipsilateral GFR at roughly 25% of normal following 1 week of complete unilateral ureteral obstruction.[53] Glomerular filtration appears to be better maintained in BUO, likely on the basis of elevated levels of atrial natriuretic peptide (ANP).[54] Secreted in response to intravascular volume expansion, ANP improves RBF and GFR through the following mechanisms:[55,56]

1. Afferent arteriolar vasodilation
2. Tubulo-glomerular feedback inhibition
3. Renin-angiotensin system (vasoconstrictive) inhibition
4. Glomerular filtration coefficient (Kf) increase.

Along with its direct natriuretic properties, the actions of ANP are thought to contribute to the diuresis, natriuresis, and rapid return to maximal renal function observed following the relief of BUO. Persistent obstruction also exerts deleterious effects on renal tubular function, primarily through the down-regulation of important transporter and co-transporter activity along the entire nephron.[57] This impairs the reabsorption of sodium (Na^+), potassium (K^+), hydrogen (H^+), and water, which, in turn, dissipates the medullary solute gradient and limits the generation of concentrated urine. Together, glomerular and tubular dysfunction manifest as profound natriuresis and diuresis following the relief of BUO.

MECHANISM

POD may involve a water diuresis, a solute diuresis, or a combination thereof. In most cases, POD represents an appropriate and self-limited physiologic response to volume and solute overload. On occasion, however, the diuresis may extend inappropriately beyond the euvolemic state, usually as a result of excessive free-water loss caused by collecting duct insensitivity to antidiuretic hormone (i.e., nephrogenic diabetes insipidus). Similar to physiologic POD, this form of diuresis is often self-limited and easily managed. True pathologic POD usually refers to the inappropriate excretion of both water and solute as reflected by a urine osmolality >250 mOsm/kg water (Table 5.4).[58] The inability to concentrate urine in pathologic POD stems from the defective distal tubular sodium reabsorption and loss of the medullary solute gradient. Reasons for this include the following:[58]

1. Decreased reabsorption of sodium chloride in the loop of Henle and distal tubule
2. Decreased reabsorption of urea in the collecting tubule
3. Medullary solute washout caused by increased medullary blood flow
4. Increased tubular flow rate and solute concentration in the distal tubule.

Table 5.4 Diuresis Subtype Based on Urine and Plasma Osmolalities

Diuresis	Uosm (mOsm/kg Water)	Uosm : Posm
Pure water	<150	<0.9
Solute	≥250	>0.9
Mixed	≥250	<0.9

Posm, plasma osmolality; Uosm, urine osmolality
(Adapted from Gulmi FA, Felsen D, Vaughan ED. Management of post-obstructive diuresis. AUA Update Series. 1998;17(23):177-83.)

PRESENTATION

The manner of presentation of urinary obstruction depends on the etiology, the time over which it develops, whether it is unilateral or bilateral, and whether it is complete or partial. In the context of chronic BUO, the signs and symptoms are often nonspecific. Although most patients with complete obstruction describe anuria or oliguria, some patients with partial obstruction may report polyuria secondary to impaired renal concentrating ability.

Volume expansion is common and may present as weight gain, peripheral edema, or even shortness of breath if CHF is a complicating factor. Patients with long-standing obstruction may present with uremic symptoms including mental status change, tremor, and gastrointestinal (GI) bleeding. Volume expansion or azotemia in the setting of BUO should raise suspicion for possible diuresis following the relief of obstruction. As such, these patients should be monitored and treated accordingly. In clinical practice, a urine output in excess of 200 mL/hr over 12 consecutive hours constitutes POD.[58] It is important to note, however, that significant derangement in fluid and electrolyte status can take place during the initial 12 hours and, as such, appropriate investigation and treatment should not be delayed.

EVALUATION AND MANAGEMENT

Upon presenting with BUO, patients should undergo a thorough baseline evaluation including a complete blood count (CBC) and complete metabolic profile. Elevations in serum blood urea nitrogen (BUN) and creatinine may be identified as well as hyperkalemia and metabolic acidosis, which require correction. The development of a brisk diuresis (>200 mL/hr) following the relief of obstruction constitutes POD and warrants appropriate monitoring, investigation, and, when appropriate, treatment.

Most cases represent physiologic POD and, as such, the diuresis is allowed to proceed until the euvolemic state is reached as determined by clinical parameters such as orthostatic vital signs, breath sounds, jugular venous distention, and peripheral edema. During this time, serum electrolytes should be evaluated every 6 to 12 hours because electrolyte imbalance, particularly hypokalemia and hypomagnesemia, may develop.[59]

If the diuresis persists beyond the euvolemic state, a pathologic concentrating defect or salt wasting nephropathy should be suspected. In this case, urinary diagnostic indices are useful to determine the type of diuresis (water versus solute versus mixed) and to guide fluid replacement (see Table 5.4). With excessive free water loss, plasma osmolality will rise while urine osmolality remains inappropriately low (<150 mOsm/kg water).

Most patients with an intact thirst mechanism and free access to water can compensate for this defect. Patients in whom oral replacement is not an option because of mental status, nil per os (NPO) status, or limited access to water require IV supplementation with hypotonic saline solutions (0.45% NaCl).

Most recommendations call for the replacement of half the urine output at 2 hourly intervals so as to not perpetuate the diuresis. However, animal models suggest that maintenance of a volume-expanded state may improve ultimate renal recovery.[60] This has led some centers to replace the entire urine output until renal function plateaus. Contraindications to excessive hydration include CHF and hypertensive crisis. Fluid replacement may be withheld in these cases until such time that the heart failure or hypertension resolves with diuresis and appropriate medical management.

Pathologic POD secondary to salt-wasting nephropathy is a rare, yet potentially life-threatening, event. Dehydration and electrolyte imbalance (Na^+, K^+, magnesium [Mg^{2+}]) are common as the persistent natriuresis promotes the loss of water, potassium, and magnesium. Urine osmolality (≥250 mOsm/kg water) is often slightly higher than that of plasma. These patients warrant careful hemodynamic monitoring, possibly including CVP, as well as frequent monitoring of both serum and urine electrolytes.

Sodium and volume replacement is accomplished using normal saline (0.9% NaCl) supplemented on occasion with hypertonic saline (3% NaCl) if the sodium deficit is profound. Serum and urine electrolytes serve as a guide in this regard. Volume replacement should match urine output in a 1 : 1 fashion until vital signs and renal function stabilize. Hypokalemia and hypomagnesemia are common and require correction. Hyperkalemia and acidosis also may occur, particularly in the event of profound dehydration and consequent worsening of renal function.

Metabolic Complications of Urinary Diversion

Metabolic complications are common to all forms of bowel urinary diversion as a result of continued solute transport by the interposed segment. These include electrolyte and acid–base abnormalities, altered sensorium, drug toxicity, osteomalacia, urinary calculi, and GI malabsorption syndromes. Factors that influence the type and severity of such complications include the following:[61]

1. Segment of bowel used
2. Surface area (length of bowel)
3. Contact time with urine
4. Urine composition (solutes, pH)
5. Renal function.

These factors are particularly important with regard to the development of electrolyte and acid–base disturbance, the focus of this discussion.

GASTROINTESTINAL TRANSPORT OF WATER AND ELECTROLYTES

A basic understanding of GI transport facilitates the management of potential complications. The primary functions of the GI tract are digestion, absorption of water and nutrients, and excretion of solid waste. Water and electrolyte transport occurs through the paracellular and transcellular pathways.[61]

A Na^+/K^+ ATPase located on the basolateral membrane drives the transport of water and solute across the intestinal mucosa by generating an electrochemical gradient. This gradient favors the absorption of sodium through luminal Na^+/H^+ exchange or noncoupled Na^+ channels. Variable expression of luminal transport proteins helps to explain differences in the type, incidence, and severity of electrolyte abnormalities amongst the different bowel segments used for urinary reconstruction. For example, the jejunum has very loose intracellular junctions, allowing for the rapid movement of fluid and electrolytes through paracellular pathways. It also lacks a Na^+/H^+ antiporter but has a Cl^-/HCO_3^- antiporter, which allows for movement of bicarbonate and chloride.

Sodium rapidly follows the existing concentration gradient such as that between plasma (140 mEq/L) and urine (20–40 mEq/L). The frequent association of hyponatremia and hypovolemia with jejunal conduits reflects this fact. Chloride absorption is linked to bicarbonate secretion throughout the small bowel and colon.[61] Bicarbonate, generated by intracellular carbonic anhydrase, is secreted in a 1 : 1 ratio for chloride. In contrast, gastric parietal cells generate bicarbonate for systemic absorption in the process of acid (H^+) secretion in exchange for potassium. The ileum and colon have less permeable intracellular junctions and can exchange both Na^+/H^+ and Cl^-/HCO_3^-.[62–64] For the most part, the intestinal transport of potassium is passive as dictated by the electrochemical gradient and movement of water. The luminal concentration of potassium is an important determinant of net potassium secretion or absorption.[65]

The majority of water transport and a minority of solute transport occurs paracellularly. GI osmotic permeability, as determined by mucosal tight junctions, decreases caudally such that the permeability of proximal small bowel is four to six times that of the distal ileum and colon.[66] The heightened permeability of jejunum to both solute and water explains the frequent association of electrolyte abnormalities with use of this segment.

STOMACH

The interposition of gastric mucosa in the urinary tract has been performed more commonly in pediatric patients than in adults. Purported advantages to the use of stomach include the prevention of short gut syndrome, less mucus production, a relative reduction in the risk of electrolyte or acid–base disturbance, recurrent infection, and urolithiasis.[67] The most frequent electrolyte abnormality is a hypochloremic, hypokalemic metabolic alkalosis, which occurs as a result of hydrogen, chloride, and potassium secretion (Table 5.5).[68]

Patients are also at risk for dehydration secondary to the loss of water through the gastric mucosa. Rarely does this metabolic abnormality achieve clinical significance except in cases of severe renal dysfunction or acute dehydration. Although patients with normal renal function are able to minimize the development of alkalosis through an increase in renal bicarbonate excretion, those with renal insufficiency cannot.

Table 5.5 Metabolic Abnormalities of Urinary Diversion

Segment	Electrolyte Abnormality	Treatment	Prevention
Stomach	Hyperchloremic, hypokalemic metabolic alkalosis	Rehydration with normal saline KCl replacement H_2 receptor antagonists Proton pump inhibitors	H_2 receptor antagonists Proton pump inhibitors
Jejunum	Hyponatremic, hypochloremic, hyperkalemic metabolic acidosis	Rehydration with normal saline Alkalinization (IV/PO) $NaHCO_3$	PO hydration PO NaCl supplementation PO $NaHCO_3$
Ileum or colon	Hyperchloremic metabolic acidosis ± Hypokalemia	Alkalinization (IV/PO) ± KCl replacement	PO $NaHCO_3$, sodium citrate, potassium citrate Chlorpromazine Nicotinic acid

IV, intravenous; KCl, potassium chloride; PO, oral
(Adapted from Tanrikut C, McDougal WS. Acid-base and electrolyte disorders after urinary diversion. World J Urol. 2004;22(3):168-71.)

Hypergastrinemia also may be important.[68,69] Secreted by gastrin cells in response to distention (among other stimuli), gastrin stimulates proton secretion by parietal cells through activation of the luminal H^+/K^+ ATPase. This mechanism becomes clinically relevant in cases of gastrocystoplasty wherein bladder distention caused by chronic outlet obstruction may stimulate the secretion of gastrin and precipitate this syndrome.

Symptomatic patients may present with lethargy, weakness, altered mental status, seizures, respiratory depression, and cardiac dysrhythmia.[70] Treatment begins with rehydration using IV normal saline (0.9% NaCl) and correction of hypokalemia as outlined in Table 5.5.[68] Long-term supplementation with oral salt or potassium chloride also may be of benefit.[69] Patients with persistent mild metabolic alkalosis warrant treatment with histamine-2 (H_2) receptor antagonists, which competitively inhibit histamine-mediated gastric acid secretion. Proton pump inhibitors, which directly inhibit the gastric H^+/K^+ ATPase, are useful in cases refractory to H_2 blockade.[61,68]

JEJUNUM

Of all bowel segments used for urinary reconstruction, electrolyte abnormalities occur most commonly with the use of jejunum.[68] As a result, this segment is only used when ileum or colon are either unavailable or inadvisable. The typical metabolic changes that occur when jejunum is used include hyponatremia, hypochloremia, hyperkalemia, volume contraction, and metabolic acidosis, all of which reflect the propensity of jejunum for sodium and chloride secretion and potassium and hydrogen ion absorption (see Table 5.5).[71] Significant dehydration is common because the osmotic gradient generated by sodium secretion results in the net loss of water and sodium. Hypovolemia stimulates the secretion of aldosterone, which, in turn, stimulates renal sodium reabsorption and potassium secretion.[72] This produces a urine low in sodium and high in potassium. When exposed to such urine, jejunum loses sodium and absorbs potassium as driven by the electrochemical gradient. This further perpetuates the metabolic disturbance. At least 25% or more of patients may develop metabolic changes, although only 4% are severe if short segments are used.[73–75] The incidence and severity of this syndrome also appears to be less if distal rather than proximal jejunum is used.

In severe cases, patients may present with lethargy, nausea, vomiting, dehydration, and weakness. Treatment involves rehydration with IV normal saline and correction of metabolic acidosis using sodium bicarbonate ($NaHCO_3$). In the acute setting, standard management of hyperkalemia includes the use of insulin or glucose infusion, bicarbonate infusion, and orally or rectally administered potassium-binding resins such as sodium polystyrene sulfonate (Kayexalate). In the normovolemic state, most patients are able to excrete excess potassium if renal function is normal. If this is not the case, thiazide diuretics may be used to augment the renal excretion of potassium in the long term.[76] Likewise, vigilant oral hydration and sodium chloride supplementation are recommended as prophylactic strategies.

ILEUM AND COLON

Ileum and colon, the bowel segments used most commonly in urinary diversion, possess similar transport properties. When exposed to urine in which the concentration of potassium and hydrogen is typically higher and the concentration of sodium is lower than intestinal contents, these segments secrete sodium and bicarbonate and absorb hydrogen, chloride, and ammonium.

Ammonia, generated by the kidneys, buffers free urinary hydrogen ions through the formation of ammonium. Ammonium, in turn, competes with sodium for absorption through the intestinal Na^+/H^+ antiporter, whereas bicarbonate is excreted in exchange for chloride absorption.[68,77] The net result is a hyperchloremic metabolic acidosis.[78] It appears that the absorption of ammonium chloride accounts for the majority of the acid load.[77]

Hypokalemia and total-body potassium depletion also may occur. Most commonly, this reflects intracellular potassium depletion secondary to chronic metabolic acidosis in combination with renal potassium wasting and intestinal potassium secretion.[68,79] Hypokalemia is less common with ileal versus colonic diversions because ileum demonstrates a higher capacity for potassium absorption than does colon.[80]

Hyperchloremic metabolic acidosis is not uncommon following urinary reconstruction with ileum or colon (see

Table 5.5).[78,81] In patients that have diversions with ureterosigmoidostomies, although now uncommon, the severity and frequency of this complication are much higher. In most cases, however, the metabolic disturbance is quite mild because of renal and hepatic compensation. Metabolic acidosis is minimized through an increase in acid excretion by the kidneys, whereas the toxic effects of hyperammonemia are avoided through the hepatic metabolism of ammonium to urea.[61] As discussed, the incidence and severity of metabolic disturbance depend on numerous factors including length of bowel segment (surface area), contact time with urine, and renal function. Commensurate with these risk factors, the incidence of hyperchloremic metabolic acidosis is higher with continent diversions (50%) than with conduit diversions (10–15%) using ileum or colon.[82–84] This highlights the importance of normal renal and hepatic function at baseline in patients considered for continent urinary diversion. Basic requirements for continent diversion include a serum creatinine <2.0 mg/dL and a normal urine protein concentration. Patients with a GFR >35 mL/min and minimal urine protein who are able to generate a urine pH <5.8 following ammonium chloride loading and urine osmolality >600 mOsm/kg following water deprivation also may be suitable candidates.[73] Otherwise, conduit urinary diversion is more appropriate.[85] There are no clinically significant differences in metabolic derangements between continent diversion and orthotopic bladder replacement.[86]

Patients with significant hyperchloremic metabolic acidosis may present with fatigue, weight loss, anorexia, and polydipsia. Laboratory studies reveal a significant nonanion gap metabolic acidosis with hypochloremia and azotemia. It is estimated that up to 10% of patients with conduit diversion and a higher proportion with continent diversion require treatment for chronic acidosis.[73,84] Treatment involves alkalinization and simultaneous potassium replacement. Correction of acidosis without adequate potassium repletion may precipitate or worsen hypokalemia as potassium is driven into the intracellular space. Sodium bicarbonate is used most commonly for alkalinization (1–2 g TID), but patients may suffer from flatulence. Sodium citrate (1–3 g QID) is a suitable alternative, but it has an unpleasant taste.[87] Unless potassium supplementation is contraindicated, potassium citrate may be more appropriate in patients with CHF or renal insufficiency in whom an excessive sodium load may be poorly tolerated. Nicotinic acid (500 mg to 2 g daily) or chlorpromazine (25 to 50 mg QID) has been reported to be useful in animal models, but lacks confirmatory data in humans.[73,87]

Hypocalcemia may also be a problem for patients with urinary diversions. Bone carbonate is used to continuously buffer the chronic metabolic acidosis. Calcium carbonate is mobilized from the bone to supply the buffer. Patients may require calcium supplementation daily (500 mg to 1 g).[87] In addition, patients may experience profound drops in serum phosphorus upon rapid correction of the chronic acidosis as bone stores of calcium phosphate are replenished.

Specific management considerations in patients with a continent urinary diversion are needed due to urine's prolonged contact with the intestinal surface compared to conduit diversions. This includes the establishment of prompt drainage (i.e., indwelling catheter) as well as empiric antibiotic therapy if urinary tract infection (UTI) is suspected. Urinary obstruction perpetuates the transport of water and solute across the bowel segment, whereas systemic infection has been known to precipitate ammoniagenic encephalopathy through bacterial endotoxin-induced hepatic dysfunction.

ALTERED SENSORIUM

Among patients with urinary diversion or reconstruction, an altered sensorium may develop secondary to magnesium deficiency, drug toxicity, or ammoniagenic encephalopathy. Hypomagnesemia, although uncommon, reflects GI malabsorption or renal magnesium wasting caused by chronic acidosis.[88] Drug intoxication may develop whenever a particular medication or its active metabolite is excreted unchanged by the kidneys and then absorbed systemically by interposed bowel. This may occur with such drugs as phenytoin or methotrexate, among others.[89] Although chemotherapy (including methotrexate) has been found to be equally safe among patients with continent and incontinent diversions, it seems prudent to catheterize continent patients during therapy.[90]

Excreted by the kidneys, ammonium is absorbed by the intestinal segment and transported to the liver via the portal circulation. Ammonium (or ammonia) is metabolized by the liver into urea, which is then excreted by the kidneys. Under normal conditions, hepatic metabolism is able to adapt to the increased delivery of portal ammonia such that systemic levels remain unchanged. In the setting of liver dysfunction, however, serum ammonia may accumulate to toxic proportions.

Ammoniagenic encephalopathy is a rare complication of bowel urinary diversion. Although this syndrome develops most commonly in patients with liver dysfunction, case reports also exist among patients with normal hepatic function.[91] Often, such cases involve systemic bacterial infection or UTI with urea-splitting organisms. Systemic infection may induce transient hepatic dysfunction secondary to the proliferation of bacterial endotoxin.[92] Alternately, urea-splitting bacteria may generate ammonia through the enzymatic action of urease on urea.[68,91] In both cases, the absorbed ammonia load may overwhelm hepatic metabolism and precipitate encephalopathy.

Depending upon the degree of hyperammonemia and the time course over which it develops, symptoms of encephalopathy vary from mild changes in mental state to deep coma. Evaluation includes an assessment of liver function as well as a thorough search for possible systemic or UTI. In patients with continent urinary diversion, obstruction should be ruled out because urinary stasis may augment the absorption of urinary ammonium. Acute management includes prompt urinary drainage by way of Foley catheter or rectal tube and empiric systemic antibiotics tailored toward urea-splitting bacteria.[68] Dietary protein restriction, neomycin (oral), and lactulose (oral or rectal), which reduce the production or absorption of ammonia in the GI tract, also are appropriate.[93]

References

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Chapter 5 Questions

1. The leading causes of end-stage renal disease (ESRD) are HTN and:
   a. Myocardial infarction
   b. Drug induced nephropathy
   c. IgA nephropathy
   d. Obesity
   e. Diabetes

2. A patient with ESRD is scheduled to undergo a partial nephrectomy and is found to have a prolonged bleeding time. Which of the following can be given to improve his coagulopathy?
   a. Vitamin K
   b. DDAVP
   c. Protamine sulfate
   d. Platelets
   e. Nothing; the patient needs HD

3. A diabetic male undergoes a TURP. He feels fine the next morning but a basic metabolic panel (BMP) obtained shows the following:

   Sodium: 131 mEq/L
   Potassium: 4.0 mEq/L
   Chloride: 104 mEq/L
   Bicarbonate: 26 mEq/L
   Blood urea nitrogen: 10 mg/dL
   Creatinine: 0.9 mg/dL
   Glucose: 420 mg/dL

   What's your next step in management?
   a. Fluid restriction
   b. Sodium replacement with 0.9% NaCl
   c. Sodium replacement with 3% NaCl
   d. Insulin
   e. IV furosemide

4. A 35-year-old healthy runner comes to the emergency department with a sprained ankle. Besides ankle pain he has no other complaints. A BMP is notable for sodium of 122 mEq/L. He has never had labs checked prior to this incident. At what rate should you increase his Na over a 24-hour period?
   a. 2 mEq
   b. 7 mEq
   c. 12 mEq
   d. 15 mEq
   e. 18 mEq

5. Which of the following is a requirement for SIADH?
   a. Urine sodium >20 mmol/L
   b. Serum osmolality of 280–295 mOsm/kg H_20
   c. GFR <60 mL/min
   d. Pitting edema
   e. Hyponatremia nonresponsive to thiazides

6. What is the most common electrolyte derangement during postobstructive diuresis?
   a. Hyponatremia and hypokalemia
   b. Hyponatremia and hypomagnesemia
   c. Hyponatremia and hypocalcemia
   d. Hypokalemia and hypomagnesemia
   e. Hypokalemia and hypocalcemia

7. An unconscious patient develops postobstructive diuresis after catheter placement. Urine osmolality is <150 mOsm/kg water. The best way to manage the patient's fluids is to:
   a. Restrict free water intake
   b. Provide access to free water
   c. Start maintenance intravenous normal saline (0.9% NaCl)
   d. Replace urine output 1 : 1 with normal saline
   e. Replace half urine output with hypotonic saline (0.45% NaCl)

8. Which of the following is NOT increased due to vasopressin?
   a. Aquaporin along the plasma membrane
   b. Total body water
   c. V_2 receptors on basal membrane
   d. cAMP
   e. Total number of aquaporin

9. A 10-year-old boy with a neurogenic bladder underwent a gastric bladder augmentation 2 years ago. If he is otherwise healthy, which is the most likely lab value to be seen on his BMP?
   a. Sodium = 150 mEq/L
   b. Potassium = 4.7 mEq/L
   c. Chloride = 92 mEq/L
   d. HCO_3 = 20 mEq/L
   e. Creatinine = 2.0 mg/dL

10. The longterm acidosis seen with ileum or colonic urinary diversions is associated with an increased risk of developing:
    a. Osteomalacia
    b. Hyperlipidemia
    c. Hyperkalemia
    d. Diabetes
    e. None of the above

Case Studies

CASE 1

A 65-year-old male complains of significant lower urinary tract symptoms secondary to an enlarged prostate. On transrectal ultrasound he has a 35 gram prostate. After failing medical management, he decides to undergo a transurethral resection of prostate. In the PACU the nurse pages the physicians to inform them the patient is throwing up, confused, and having difficultly seeing. His vital signs are normal. A stat CBC is normal. His BMP is below. The day prior to surgery the patient's labs were normal.

Sodium: 125 mEq/L
Potassium: 4.0 mEq/L
Chloride: 104 mEq/L

Bicarbonate: 26 mEq/L
Blood urea nitrogen: 15 mg/dL
Creatinine: 1.3 mg/dL
Glucose: 120 mg/dL

1. Which of the following is a risk factor for developing TUR syndrome?
   a. Being a nonsmoker
   b. Resection time of 95 min
   c. Incomplete resection of adenoma
   d. Irrigation with 0.9% NaCl
   e. Prostate volume of 35 grams

2. If he weighs 100 kg and an ideal serum sodium is 140 mEq/L, what's his serum sodium deficit?
   a. 300 mEq
   b. 550 mEq
   c. 900 mEq
   d. 1200 mEq
   e. 2100 mEq

3. After placing a central line, you order 3% NaCl to correct the patient's hyponatremia. To increase his serum sodium by 1 mEq/L/hr, what rate would you use?
   a. 66 mL/hr
   b. 84 mL/hr
   c. 120 mL/hr
   d. 157 mL/hr
   e. 310 mL/hr

CASE 2

A 70-year-old man was brought to the emergency department due to acute onset altered mental status. His wife reports that over the past 24 hours he had become more fatigued and less responsive. Urology is consulted because the patient had undergone cystectomy and continent urinary reservoir (CUR) creation 10 years prior for muscle invasive bladder cancer. His wife is concerned because due to his mental state he missed his last scheduled catheterization of his CUR. CT head in the ED was negative for any intracranial processes but his CT abdomen and pelvis showed bilateral grade 2 hydronephrosis and a distended CUR with stones in it. Blood work is pending.

1. Which of the following is least likely to be a cause of his change in mental status?
   a. Drug toxicity
   b. Brain metastasis
   c. Ammoniagenic encephalopathy
   d. Magnesium deficiency
   e. All of the above could cause his mental status change

2. The patient's white blood cell count, serum creatinine, blood urea nitrogen (BUN), and ammonia level are found to be elevated. Which of the following is least likely to improve the patient's condition?
   a. Bilateral nephrostomy tubes
   b. Broad spectrum antibiotics
   c. Placing a catheter into the CUR
   d. Lactulose enemas
   e. Fluid resuscitation

3. The patient makes a speedy recover after initiation of the appropriate treatments. Before they leave the hospital, the patient's wife asks if there was any reason 10 years ago that her husband should not have been allowed to get a CUR. Which of the following would have been a contraindication to this patient getting a continent diversion?
   a. Age >55
   b. Recurrent urinary tract infections
   c. Bilateral hydronephrosis
   d. A history of nephrolithiasis
   e. Serum creatinine of 2.2 mg/dL

Answers

1. **e.** Diabetes and HTN are the two most common causes of ESRD.
2. **b.** Increased bleeding time associated with ESRD is due to an abnormality in von Willebrand's factor (vWF)-related platelet aggregation and platelet–vessel wall interaction. Measures to correct this include administration of cryoprecipitate, factor III, or DDAVP (1-deamino-8-D-arginine vasopressin), all of which raise circulating levels of vWF.
3. **d.** This patient has hyper-osmolar hyponatremia secondary to hyperglycemia. With the correction factor of 2.4 mEq/L per 100 mg/dL glucose greater than 100 mg/dL, this patient's serum sodium is
$$138\ \text{mEq/L} = 131 + 2.4 * \frac{420 - 100}{100}$$
4. **b.** Because duration is unknown and the patient is asymptomatic, aggressive replacement should not be attempted due to concern of osmotic demyelination syndrome. The 24-hour goal is increase serum Na by at least 4–8 mEq/day but do not exceed 10–12 mEq/L in any 24-hour period.
5. **a.** SIADH is a result of increased vasopressin leading to inappropriately concentrated urine with urine sodium >20 mmol/L. See Box 5.1 for the complete list of criteria for SIADH including serum osmolality is <280 mOsm/kg H_20. Kidney disease is not a requirement for SIADH, pitting edema suggests fluid overload not euvolemia, and response to thiazides is not a diagnostic test used for SIADH.
6. **d.** In POD serum electrolytes should be evaluated every 6 to 12 hours because electrolyte imbalance, particularly hypokalemia and hypomagnesemia, may develop.
7. **e.** This patient is losing hypotonic fluid without the ability to self-regulate to thirst. The inappropriately low osmolality of the urine will cause excess free water loss and result in an increased plasma osmolality. To accommodate this a hypotonic solution should be used. To avoid perpetuating diuresis, only half of the patient's urine output is replaced.
8. **c.** Vasopressin activates V_2 to increase cAMP via adenyl cyclase, which causes the transportation of

intracellular vesicles containing aquaporin-2 to the apical plasma membrane along with up-regulation of aquaporin-2 synthesis. Aquaporins allow water reabsorption through the plasma membrane of the collecting duct. The number of V_2 receptors is unchanged.

9. **c.** The most frequent electrolyte abnormality when the stomach is used for augmentation or diversion is a hypochloremic, hypokalemic metabolic alkalosis, which occurs as a result of hydrogen, chloride, and potassium secretion and bicarbonate generation/systemic absorption.
10. **a.** Osteomalacia due to hypocalcemia. Bone carbonate is used to continuously buffer the chronic metabolic acidosis. Calcium carbonate is mobilized from the bone to supply the buffer. Increased serum calcium is renally excreted, where, due to acidosis, reabsorption of calcium is inhibited. Patients may require calcium supplementation daily (500 mg to 1 g).

CASE 1

1. **b.** Resection time >90 min has an increased risk of TUR syndrome, as does being a smoker, irrigation of hypotonic fluids such as water or glycine, and a prostate larger than 45 grams. See Box 5.2 for a list of risk factors for TUR syndrome.
2. **c.** Sodium deficit = Total body water (TBW) × (Desired serum Na − Actual serum Na). The patient's TBW = 60% of total body weight; therefore Sodium deficit = 60L * (140 mEq/L − 125 mEq/L). The patient's sodium deficit is 900 mEq of Na.
3. **d.** Using the Adrogue formula: The increase in the patient's serum sodium if 1000 mL of a fluid was given

$$= \frac{\begin{array}{c}[\text{Sodium in infusion fluid}] \\ +[\text{Potassium in infusion fluid}] \\ -[\text{Patient's serum sodium}]\end{array}}{(\text{TBW}+1)}$$

Therefore per liter of 3% NaCl the equation would be

$$\frac{(513\ \text{mEq/L Na} + 0\ \text{mEq/L K} - 125\ \text{mEq/L Na})}{(60+1)}$$

$$= 6.36\ \text{mEq/L}$$

increase in serum sodium per liter of 3% NaCl administered.

If the goal rate of serum sodium change per hour is 1 mEq/L/hr, the rate of infusion of 3% NaCl is calculated by:

$$\frac{1000\ \text{mL} * \text{Goal rate of serum sodium concentration change (mEq/L/hr)}}{\text{Increase in the patient's serum sodium if 1000 ml of fluid were administered}}$$

$$\text{Infusion rate} = \frac{1000\ \text{mL 3\% NaCl} * 1\ \text{mEq/L/hr}}{6.36\ \text{mEq/L}}$$

$$= 157\ \text{mL/hr}$$

CASE 2

1. **b.** Drug toxicity, ammoniagenic encephalopathy, and magnesium deficiency can all cause altered sensorium. With acute onset and a negative head CT it is unlikely that a brain metastasis caused his mental status changes.
2. **a.** The treatment of ammoniagenic encephalopathy includes prompt urinary drainage by way of Foley catheter and empiric systemic antibiotics tailored toward urea-splitting bacteria. Dietary protein restriction, neomycin (oral), and lactulose (oral or rectal), which reduce the production or absorption of ammonia in the GI tract, also are appropriate. His hydronephrosis is likely due to a distended reservoir, and his elevated BUN and creatinine could be due to dehydration. Bilateral nephrostomy tubes would only be necessary if the patient was found to have an obstruction of his ureters.
3. **e.** Basic requirements for continent diversion include a serum creatinine <2.0 mg/dL and a normal urine protein concentration. Patients with a GFR >35 mL/min and minimal urine protein who are able to generate a urine pH <5.8 following ammonium chloride loading and urine osmolality >600 mOsm/kg following water deprivation also may be suitable candidates. The other options are not contraindications for undergoing creation of a continent urinary diversion.

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6 Anesthetic Complications in Urologic Surgery

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CHAPTER OUTLINE

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Chapter 6 Questions and Answers

KEY POINTS

1. Urologic diagnostic and therapeutic procedures can often induce surgical site infections, urinary tract infections, and sepsis; most procedures need to be covered with prophylactic antibiotics. Prophylaxis should be done within 60 minutes of surgical incision. If there is an active infection or any infectious source (e.g., Foley catheter) preoperatively, it should be diagnosed (urinalysis, culture and sensitivity) and specifically treated before surgery. Choice of antibiotics is hospital-specific, and the most active antibiotics are reserved for therapy.
2. The ASA classification system is a useful tool for perioperative risk stratification in conjunction with a specific surgery. Choice of anesthesia must be tailored specifically to the patient (e.g., age, comorbidities), the specific procedure (e.g., potential complications, surgical site, length and difficulty of surgery, patient positioning), and the skills of both the anesthesiologist and the surgeon. Deciding which anesthesia technique to use is a complex by-product of thorough preoperative assessment and good communication between the anesthesiologist and urologist.
3. Adverse pulmonary events are the cause of most anesthetic complications under general anesthesia. Inadequate ventilation, esophageal intubation, and difficult tracheal intubation are responsible for most of these injuries. Less common but equally important mechanisms of adverse respiratory-related events include airway obstruction, bronchospasm, aspiration, airway trauma, and pneumothorax. Proper airway management is essential in order to avoid most of these complications.
4. When there are no contraindications, regional anesthesia (spinal, epidural, CSE) and peripheral nerve blocks are good choices for most urologic surgeries. They ensure good surgical analgesia; fast, alert, comfortable recovery; and excellent postoperative pain relief (8–12 hours) when meperidine spinal anesthesia is used.
5. Complications of regional anesthesia include hypotension, postdural puncture headache, cauda equina syndrome/transient neurologic symptoms, total spinal through inadvertent subarachnoid injection, and systemic local anesthetic toxicity through inadvertent intravascular injection. Although these complications are rare, awareness of them must be maintained and proper patient monitoring and safeguards used.
6. Two of the most common debilitating conditions in the recovery room are pain and postoperative nausea and vomiting (PONV). Both conditions are largely preventable. The use of regional anesthesia, nerve blocks, and meperidine spinal anesthesia can prevent or minimize pain while providing stress-free anesthesia. Most PONV can be prevented by avoiding inhalational anesthetics, N_2O, and unnecessary intraoperative sedatives. Using antiemetics early, along with propofol total intravenous anesthesia (TIVA), further reduces the incidence and severity of PONV, even in high-risk patients.
7. Pudendal and penile nerve blocks are minimally invasive and easy to perform. They are good primary or adjuvant methods for surgical analgesia and postoperative pain relief. These blocks are especially safe and useful in old and sick ASA III/IV patients because they eliminate the risks and complications caused by general anesthesia while providing a stress-free operative and postoperative course (no pain, no PONV, clear postoperative mentation).
8. The prevalence of obesity and frequently associated obstructive sleep apnea (OSA) are increasing. Morbid obesity, when associated with significant comorbidities (coronary artery disease, heart failure, atrial fibrillation, hypertension, kidney disease, metabolic syndrome), poses significant risk and increases poor outcomes. OSA may further aggravate these outcomes. Thorough preoperative evaluation combined with proper patient triage, use of regional anesthesia and perioperative supportive continuous positive airway pressure/bilevel positive airway pressure (CPAP/BiPAP) may improve morbidity and mortality.

9. The best postoperative pain management is based on intravenous or epidural patient-controlled analgesia or a judicious multimodal pain management using narcotics, NSAIDs, acetaminophen, tramadol, etc. Ideally, specific protocol-based management will provide best outcomes.
10. A wide array of urology cases are being performed laparoscopically and robotically. Intimate knowledge of CO_2 insufflation pathophysiology is essential. Intraoperative complications such as shoulder pain, subcutaneous emphysema, pneumopericardium, pneumomediastinum, pneumothorax, tension pneumothorax, and CO_2 gas embolism must be understood, recognized, treated, and prevented. Serious largely preventable positioning complications in laparoscopic/robotic surgery include specific nerve damage, compartment syndrome, and rhabdomyolysis.

Urologists gain significantly from understanding different anesthesia techniques – their risks, their benefits, and their complications. Thorough knowledge of the patient's preexisting medical, surgical, and psychological condition is essential to design a judicious surgical and anesthesia plan. The best and safest results are produced when the urologist and anesthesiologist pursue an integrated strategy together.

This chapter is organized around preoperative, intraoperative, and postoperative management, with a focus on choice of anesthesia technique (general, regional, and peripheral nerve blocks), and the treatment and prevention of complications. Additionally, the chapter includes sections covering the special anesthetic management and complications of urologic laparoscopy/robotic-assisted laparoscopy.

Anesthesia Safety

Safety of anesthesia has been steadily improving for the past several decades. The incidence of anesthetic mortality in which anesthesia was the primary cause of death improved steadily from 1 per 14,075[1] to 1 per 300,000 anesthetics administered.[2] There are multiple reasons for these significant improvements, including more targeted preoperative testing, better intraoperative monitoring, better expert clinical training[3] for anesthesiologists including simulation training,[4] creation of patient-centered clinical pathways and protocols developed from evidence-based medicine, and increased awareness and knowledge of potential surgical and anesthesia complications.

Preoperative Assessment

The best choice of anesthetic technique for any urologic procedure requires a thorough preoperative evaluation of the patient. This minimally includes a detailed assessment of cardiac risks, pulmonary risks and airway, infectious complication risks, and anticoagulation risks. All these data, along with the American Society of Anesthesiologists (ASA) anesthesia risk classification and an understanding of procedure-specific surgical and anesthetic risks, influence the choice of anesthesia technique.

PREANESTHETIC EVALUATION

A preanesthesia evaluation involves assessment of information from multiple sources, including patient's history and physical examination, previous medical records, and findings from preoperative tests. According to the ASA practice advisory for preanesthesia evaluation,[5] the patient's history and physical condition should dictate what kind of preoperative testing is appropriate, and routine preoperative testing should be avoided. A presurgical testing unit (PST) is very useful in determining what selective preoperative tests should be obtained. Each hospital should have its own experience-based decision-making parameters for the timing, quality, and quantity of the specific preoperative tests required for each given procedure. It is beyond the scope of this chapter to greatly detail all required preoperative testing regimens for urologic surgery.

At a minimum, however, complete blood cell count (CBC), basic metabolic panel, blood urea nitrogen (BUN)/creatinine, and urinalysis are obtained. If urinalysis is positive, a culture and sensitivity (C&S) test is obtained and patients are placed preoperatively on a culture-specific antibiotic in order to prevent bacteremia and possibly urosepsis during surgery.

The patient's preexisting cardiac and pulmonary conditions are the two most common risks for anesthetic morbidity and mortality. Additionally, increasingly prevalent significant risks include morbid obesity and obstructive sleep apnea (OSA).

ANESTHESIA RISK: THE AMERICAN SOCIETY OF ANESTHESIOLOGISTS PHYSICAL STATUS CLASSIFICATION SYSTEM

Once all the preoperative information is evaluated, the anesthesiologist assigns an ASA score. The score is intended to create a uniform system of describing the patient's preoperative physical condition. ASA classification is important because studies have demonstrated that with increasing ASA class, there is increased incidence of adverse events and adverse outcomes.[6]

The modern classification system consists of the following six physical status categories:

ASA I: Normal healthy patient
ASA II: Patient with one mild systemic disease

ASA III: Patient with two severe systemic diseases
ASA IV: Patient with several systemic diseases, at least one life threatening
ASA V: Moribund patient who is not expected to survive without the operation
ASA VI: Declared brain-dead patient who will become an organ donor

CHOICE OF ANESTHESIA TECHNIQUE IN UROLOGIC SURGERY

Adult patients requiring anesthesia for renal and genitourinary surgery are often very old, and they may have a host of comorbidities, which pose serious problems before, during, and after surgery and anesthesia. The choice of anesthetic technique depends on a myriad of factors, including the patient's preexisting conditions; type, site, and length of surgery to be performed; skill of the urologist and anesthesiologist and their intimate knowledge of potential surgical and anesthetic complications; and predictability and limitations of the surgical and anesthesia procedures. Based on all of these factors, the ultimate decision of anesthesia method needs to be the product of a well-informed discussion between the surgeon and the anesthesiologist.

Patient-specific Risk Stratification

The modern ASA classification system, in conjunction with the full preoperative workup data of the patient, provides a degree of perioperative risk stratification that is very useful in choosing the optimal anesthetic technique for a given patient undergoing a particular surgery.

ASA I patients who are young, healthy, and with good exercise tolerance and no organic physiologic or psychiatric disturbance may have general anesthesia, regional anesthesia, nerve blocks, or clinical sedation for their procedure. Any obvious difficulty with general anesthesia (e.g., difficult airway, full stomach, allergies to anesthetics, hyperreactive airway) will necessitate modifications in the general anesthesia technique (e.g., fiberoptic intubation, fast sequence induction and endotracheal intubation, avoidance of certain drugs, modification or deepening of induction). General anesthesia will be used in cases in which patient stillness during the procedure is essential, for example, brachytherapy, renal and upper ureteral stone lithotripsy, and most laparoscopic and robotic surgeries.

ASA II patients with mild systemic disease who have no functional limitations and have a well-controlled one body system disease (e.g., diabetes, hypertension [HTN], smoking without chronic obstructive pulmonary disease [COPD]) can tolerate general anesthesia as well as regional anesthesia or nerve blocks. The one system disease must be stabilized. If a patient presents with a full stomach or hyperreactive airway, regional anesthesia or nerve blocks might provide extra safety for the patient and ease postoperative recovery.

ASA III patients have severe systemic disease, involving more than one major body system. They are in no immediate danger of death, but they have some functional limitations (e.g., stable angina, congestive heart failure [CHF], old heart attack, poorly controlled hypertension and diabetes, morbid obesity, OSA, chronic renal failure). With the advent of modern monitoring and mandatory use of pulse oximetry and end-tidal carbon dioxide monitoring ($ETCO_2$), contemporary general anesthesia has greatly improved. Most recent clinical studies comparing general with regional anesthesia show no substantial difference in outcomes. However, when using general anesthesia in this patient population, utmost care must be exercised in maintaining steady normal vital signs throughout the case (e.g., use etomidate for induction, use cardiovascular support, if needed, and maintain normal blood volume). If there are no contraindications, regional anesthesia or nerve blocks with their pulmonary and cardiovascular sparing effect, along with the prolonged postoperative analgesia they provide, are our favorite modalities for predictable, stable, safe, and comfortable outcomes in this patient group.

ASA IV patients have multiple system disease, where one or more diseases may present a constant threat to life. These diseases may be poorly controlled or at their end stage (e.g., unstable angina, symptomatic COPD, symptomatic CHF, hepatorenal failure). Preoperatively, these patients require time and specialist support to maximally control their unstable diseases. Intraoperatively, heavy monitoring (e.g., A-line, central venous pressure [CVP], Swan-Ganz catheter, cardiac output, transesophageal echocardiography [TEE]) and pharmacologic cardiovascular and pulmonary support are needed. In this patient group, general anesthesia poses high risk. For urologic procedures, regional anesthesia in skilled hands, using minidoses of local anesthetic, ensures minimum respiratory and cardiovascular risk, as well as stable, comfortable, and less eventful recovery. Importantly, using only minimum sedation with the regional block, the mental status of these sicker, older patients will remain unimpaired throughout the case and during the recovery period.

Procedure-specific Indications

Because most urologic procedures are performed in an anatomic area primarily innervated by thoracolumbar and sacral nerve supply, these procedures are excellent candidates for regional anesthesia and nerve blocks. The great versatility of regional anesthesia relies on the fact that, if skillfully done, it can greatly preserve pulmonary and cardiovascular functions in all patients. This gives maximum benefit to older patients or those with severe comorbidities. Major contraindications for regional anesthesia are patient refusal, skin infection, sepsis, cardiac outflow tract obstruction (aortic stenosis, idiopathic hypertrophic subaortic stenosis [IHSS]), serious previous neurologic deficiencies, anticoagulation, shock, hypotension, or allergies to local anesthetics.

In some urologic procedures patient awareness is an advantage, as in transurethral resection of the prostate (TURP) using monopolar resectoscope, in which the patient can voice any discomfort and early symptomatology. In other procedures, slight sedation or a total intravenous anesthesia (TIVA) helps the patient tolerate the operative surroundings (operating room noises, uncomfortable positioning) and length of procedure (e.g., long perineal reconstructive procedures done under combined spinal or epidural block, radical prostatectomy under regional block, penile prosthesis insertion, artificial urinary sphincter insertion, complex female incontinence surgery, endourethral procedures, longer procedures done under pudendal or penile block).

TIVA always successfully assures physical and emotional comfort when used before/during pudendal blocks and penile blocks. Patients are unaware of the block, and after the procedure they wake up comfortable and enjoy a prolonged postoperative analgesia. A propofol-based TIVA predictably prevents postoperative nausea and vomiting (PONV) in most patients, including those with a history of PONV. See "Postoperative Nausea and Vomiting," later.

Obesity and Obstructive Sleep Apnea

The prevalence of obesity is rapidly increasing worldwide. Proportionately, the prevalence of OSA is increasing as well. Clinically, these two conditions frequently overlap. Therefore they will be treated together in this chapter.

In adults, the World Health Organization (WHO) and the National Institutes of Health (NIH) define and classify obesity with respect to body mass index (BMI) as:

Overweight: BMI ≥25–29.9 kg/m^2
Obesity: BMI ≥30 kg/m^2
Obesity Class 1: BMI of 30–34.9 kg/m^2
Obesity Class 2: BMI of 35–39.9 kg/m^2
Obesity Class 3: BMI ≥40 kg/m^2 (referred to as extreme, severe, or morbid obesity)

Planning for anesthesia must take account of two aspects of obesity: (1) physiologic changes of obesity, and (2) the presence of specific comorbidities. Other risk factors should be addressed as well.

PHYSIOLOGIC CHANGES OF OBESITY

Obesity produces changes in respiratory, cardiovascular, and airway physiology (difficult ventilation/intubation), which may impact anesthesia delivery to these patients.

Respiratory Physiology

Extra body weight will lead to increased work of breathing and oxygen consumption, as well as a disordered ventilation/perfusion (V/Q) ratio. The lung volumes, functional residual capacity (FRC), and expiratory reserve volume (ERV) are decreased while the respiratory rate (RR) is increased.[7] V/Q mismatch and intrapulmonary shunts increase during general anesthesia (GA) to a greater degree in obese patients. Supine position and OSA will exaggerate these changes.[8,9]

Cardiovascular Physiology

Extra body weight will lead to an increase in blood volume;[10] decrease in systemic vascular resistance;[11] and an increase in cardiac output (CO), which occurs mostly due to an increase in stroke volume,[12] which may lead to heart failure, especially when associated with chronic hypoxia of OSA. Frequently, there is left ventricular hypertrophy (LVH) directly proportionate with the duration of obesity. Hypertension (HTN), which is prevalent in obese patients, may aggravate the entire picture and produces additional physiologic changes.

Dosing of anesthetic drugs is difficult and complex in obese patients. It should be modified because of significant changes in regional blood flow and increases in CO and blood volume. When the recommended dosing scheme is not known, the use of medications should be based on lean body weight (LBW), except with lipophilic drugs, where total body weight (TBW) should be used.

COMORBIDITIES ASSOCIATED WITH OBESITY

Healthy Class 1 obese patients do not seem to be at increased risk of adverse outcomes following noncardiac surgery.[13] However, there is an increase in postoperative morbidity and mortality in morbidly obese patients presenting with comorbidities. A targeted history and physical (H&P) and some additional testing must be obtained and discussed by the medical, surgical, and anesthesia team. It is very important to identify and optimize comorbidities as part of planning for surgery.[14]

Comorbidities prevalent in obese patients may include OSA, obesity hypoventilation syndrome (OHS), heart disease (CAD, heart failure, arrhythmias, HTN), metabolic syndrome, diabetes mellitus (DM), and kidney disease. During preoperative screening, the stage of comorbidities should be evaluated to assess their impact on perioperative management in order to minimize complications from surgery and anesthesia.

Obstructive Sleep Apnea

Obstructive sleep apnea, a prevalent respiratory risk condition in morbidly obese patients, is characterized by repetitive bouts of apnea, hypopnea, and hypoxia during sleep. Obstructive sleep apnea impacts patients' responses to narcotics and sedatives, exaggerating their respiratory depressant effect, and affects the airway (difficult ventilation, intubation). Obstructive sleep apnea is associated with specific cardiovascular effects, which include coronary artery disease (CAD), HTN, pulmonary hypertension, and frequent cardiac arrhythmias. A frequently associated condition is OHS, which is defined as chronic hypoventilation in an awake patient (a CO_2 >45 mm Hg). These patients tend to have pulmonary hypertension, and they are extremely sensitive to the respiratory depressant effects of narcotics and sedatives. Continuous positive airway pressure (CPAP) is frequently needed to support better oxygenation postoperatively. Preoperatively the OHS patient should have an echocardiogram to assess cardiac function and a baseline arterial blood gas (ABG) and chemistries (bicarbonate) to assess the degree of chronic hypercapnia.

Coronary Artery Disease, Heart Failure, and Atrial Fibrillation

CAD, HF, and AF are more common in obese patients and should be recently diagnosed and stabilized preoperatively. Exercise tolerance should be gauged by history and stress test. The American Heart Association (AHA) scientific advisory on obesity recommended in 2009 that obese patients with even one risk factor for CAD (smoking, DM, HTN, or hyperlipidemia) or with poor exercise tolerance should obtain a 12-lead EKG and chest X-ray (BMI >40) in addition to the regular preoperative workup recommended for patients with a normal BMI.[15]

Hypertension

Hypertension is frequently associated with obesity and should be controlled/steadied preoperatively. If BP

>170/110, the case should be postponed and the patient medically stabilized at lower levels of BP. Labile BP during surgery is frequently associated with serious cardiac, renal, and neurologic complications.

Metabolic Syndrome

Metabolic syndrome is associated with greater frequency of complications during surgery. It is characterized by a host of risk factors leading to cardiovascular disease and type 2 DM. Abdominal obesity, dyslipidemia, HTN, and hyperglycemia should be assessed and optimized preoperatively.

Kidney Disease

In morbidly obese patients, it is recommended to obtain a creatinine (Cr) and a GFR prior to major surgeries.

OTHER PREOPERATIVE RISK FACTORS IN OBESITY: DIFFICULT AIRWAY

There are certain predictors of difficult mask ventilation and difficult intubation.

Predictors of difficult mask ventilation are BMI >30 kg/m^2, history of OSA, lack of teeth, presence of beard, age >55, Mallampati III-IV (difficult airway), limited mandibular protrusion test, male gender, and presence of airway masses (tumors, deformities).[16,17]

Predictors of difficult laryngoscopy and intubation are Mallampati III-IV, previous difficult intubation, large circumference of neck, and male gender.[18,19]

PREOPERATIVE CONSIDERATIONS FOR OBESE AND OBSTRUCTIVE SLEEP APNEA PATIENTS

Most general preoperative measures like nil per os (NPO) and medications (doses, timing, etc.) are the same as for nonobese patients. Additionally, BP, blood sugar, and screening for OSA (sleep clinic, home test, STOP-BANG) should be considered. Also, patients should be evaluated for difficult airway, difficult intubation, and chance of rapid hypoxia.

Lap Band

In order to avoid aspiration pneumonitis, patients with previous weight loss surgery (e.g., lap band) will need to have their band released preoperatively by the hospital bariatric team. Even after band release, patients with a history of frequent post–lab band reflux should have their airway protected (endotracheal intubation).

Ambulatory Versus Inpatient

Deciding whether to do surgery in an ambulatory or inpatient setting should be an individualized decision, based on close cooperation between the patient's primary care physician (PCP), surgeon, and anesthesiologist. It is accepted that super-obesity (BMI >50 kg/m^2) might influence outcomes after ambulatory procedures, especially in patients with comorbidities. Several studies report factors influencing morbidity and mortality in ambulatory surgery on the super-obese: BMI >53, inability to walk over 200 feet, history of deep vein thrombosis (DVT), history of OSA, other coexisting medical conditions, and type of surgical procedure.[20] Another study reports higher ASA physical status and longer operations significantly increase mortality for this group.[21]

However, ambulatory surgeries of all kinds are routinely done on morbidly obese patients without undue complications or hospital admissions.[22] To assure safety, proper equipment should be available, e.g., advanced respiratory and intubation tools, proper capacity beds, and appropriate x-ray and lab facilities. For best results, proper clinical protocols and pathways for the care of the morbidly obese should be established.

Obese Patients With Preoperative Diagnosis of Obstructive Sleep Apnea or Obesity Hyperventilation Syndrome

This patient population benefits from daily preoperative use of CPAP or bilevel positive airway pressure (BiPAP), which produces an increase in pharyngeal area, a decrease of tongue volume (which occurs in about 4–6 weeks of therapy),[23] improved ventilatory drive,[24] and improvement of most cardiac parameters.[24–26] Furthermore, recent studies have suggested the utility of CPAP/BiPAP for several days postoperatively when a patient's condition might worsen at home. These patients should be encouraged to use their CPAP or BiPAP both pre- and postoperatively. In some cases of newly diagnosed OHS and/or OSA, surgery might need to be delayed (if it is not an emergency) until the above positive changes can be effected. BiPAP appears to be somewhat superior to CPAP in obtaining these improvements.[27,28]

STRATEGIES FOR ANESTHESIA AND PAIN MANAGEMENT IN OBESE/OBSTRUCTIVE SLEEP APNEA PATIENTS

For obese/OSA patients, regional anesthesia is a safer choice than general anesthesia.[29] Regional anesthesia also may obviate the need for postoperative narcotics and sedatives (thus avoiding their respiratory depressant effect).

If general anesthesia is required, dexmedetomidine is superior to inhalational anesthesia.[30] Ketamine is a useful anesthetic, which also provides prolonged postoperative analgesia.[31–33]

In the context of postoperative multimodal analgesia, acetaminophen IV[34,35] and NSAIDS (e.g., Celebrex, diclofenac, ibuprofen IV, and ketorolac) prove effective (allowing decreased use of opioids). Other opioid-sparing drugs like steroids,[36] pregabalin,[37] tramadol,[38] tapentadol,[39] and dexmedetomidine[40] can be used successfully.

Intraoperative Anesthesia Management

Anesthesia for urologic surgery includes general anesthesia, regional anesthesia, and specific nerve blocks. Each technique has its own specific complications.

COMPLICATIONS DURING GENERAL ANESTHESIA

Adverse pulmonary events are the cause of most anesthetic complications that occur under general anesthesia. In

Caplan's study of the ASA closed claims database, adverse respiratory events accounted for 34% of all adverse events, with death or brain damage occurring in 85% of those patients.[41] Three mechanisms accounted for 75% of these injuries: inadequate ventilation, esophageal intubation, and difficult tracheal intubation.

Less common but equally important mechanisms of adverse respiratory-related events included airway obstruction, bronchospasm, aspiration of gastric contents, airway trauma, and pneumothorax.[42] Proper airway management is essential in avoiding most of these pulmonary event–related anesthetic complications. Other specific complications occurring during general anesthesia administered for urologic procedures also will be mentioned.

Difficult Airway

When the anesthesiologist has difficulty in ventilating or intubating the patient, the airway is defined as difficult. The ASA has devised a complex algorithm to help manage the difficult airway. Preoperatively, the most important question is whether or not oxygenation and ventilation can be provided.[43] Using a laryngeal mask airway (LMA), videoscope or fiberoptic intubation can help solve this problem. Alternatively, using regional anesthesia will circumvent these difficulties. In extreme cases, surgical technique might need to be adapted to the modified anesthesia choice.

Hyperreactive Airway and Bronchospasm

Hyperreactive airway can be anticipated by taking a thorough history and physical. Patients with bronchial asthma (or with a history of it), obesity, or COPD, smokers, patients with atopies (e.g., eczema), or those with recent upper respiratory infections (within 4–6 weeks) frequently present either with a hyperreactive airway or with an overt asthmatic condition. Their usual medications, such as β_2-agonists (e.g., albuterol) and anticholinergics (e.g., ipratropium), should be used preoperatively. Most importantly, an adequate depth of anesthesia should be achieved before manipulating the airway with endotracheal intubation or before patient positioning and any surgical manipulation. The same principle applies when extubating these patients. In this patient population, regional anesthesia techniques are preferable, whenever feasible.

Aspiration Pneumonitis

Aspiration pneumonitis due to aspiration of gastrointestinal contents is associated with a significant degree of morbidity and mortality, especially in patients ASA III and above. Many risk factors exist for aspiration, including full stomach, gastroesophageal reflux disease (GERD), hiatal hernia, ileus or bowel obstruction, pregnancy, obesity, diabetes, emergency cases, trauma, gastric motility disorders, inadequate general anesthesia, difficult intubation, enteral tube feeding, sepsis, and severe renal failure.

Aspiration occurs because the protective airway reflexes (e.g., gag, cough) are missing or blunted by anesthesia. For prevention, patients should be NPO before surgery 6–8 hours for solids and 2 hours for clear liquids. A host of pharmacologic agents may be used preoperatively to diminish gastric acidity and/or volume (e.g., antacids; proton pump inhibitors, such as omeprazole; histamine-2 receptor antagonists, such as cimetidine, famotidine, and ranitidine; or gastrointestinal stimulants, such as metoclopramide). For patients at risk of aspiration pneumonitis, rapid sequence induction and endotracheal intubation should be used in all general anesthesia cases. Alternatively, aspiration of stomach contents can be avoided by using a regional anesthesia technique.

Laryngeal, Pharyngeal, and Esophageal Trauma

In an ASA closed claims analysis, the larynx was the most common site of injury (33%), followed by the pharynx (19%) and the esophagus (18%).[41] Most airway injuries are of minor significance and are temporary, although some can result in severe sequelae (e.g., mediastinitis) or even death. Whenever a difficult intubation is encountered or if the patient complains of specific symptoms postoperatively, the surgeon and the anesthesiologist should keep a high index of suspicion for airway injury. These injuries may require further evaluation by an otolaryngologist and further intervention.

Avoiding intubation altogether (regional anesthesia) or using fiberoptic laryngoscopy, a videoscope, or LMA will prevent most of these complications.

Airway Obstruction

Airway obstruction occurs with some frequency during anesthesia. Most airway obstructions (89%) occur during general anesthesia, and 70% of these involve the upper airway.[42] Causes of upper airway obstruction may include laryngospasm, foreign body, laryngeal polyps, laryngeal edema, pharyngeal hematoma, kinked endotracheal tube (ETT), and kinked breathing circuits. Tracheobronchial obstruction may occur as well, usually secondary to blood or mucus in the lumen or external compression from a mass (e.g., tumor, mediastinal mass, hematoma, thoracoscopy). Airway obstruction also may occur during monitored anesthesia care (MAC). Intense unrelieved airway obstruction in a spontaneously breathing patient may even cause negative pressure pulmonary edema.

Most cases of airway obstruction can be relieved with proper airway management or placement of an LMA or an ETT. Cautious placement of a nasal trumpet can be invaluable in preventing and relieving airway obstruction, especially in MAC cases. Vigilance is the key in preventing airway obstruction – watching the patient's chest and diaphragmatic movement, looking and feeling for exhaled air – along with $ETCO_2$ and airway pressure monitoring.

Pneumothorax

Pneumothorax is a relatively rare complication. Most causes for pneumothorax may be divided into two categories: needle related or airway-management related. Most needle-related pneumothorax cases are due to nerve blocks or central venous catheter placement. Airway management–related pneumothorax cases involve airway instrumentation (e.g., laryngoscopy, ETT placement, bronchoscopy) and barotrauma (e.g., ventilator).[42]

Specific urologic procedures are associated with a higher incidence of pneumothorax. Procedures performed abutting the diaphragm (e.g., nephrectomy, partial nephrectomy, percutaneous nephrolithotomy [PCNL]) and laparoscopic cases run the risk of puncturing the diaphragm and creating a pneumothorax. Pneumothorax should be suspected

when there is an increase in the patient's respiratory rate and peak airway pressure, hypoxemia, hypercarbia, and hemodynamic changes, particularly hypotension and mediastinal shift, as in tension pneumothorax (which is an emergency). Definitive diagnoses can be confirmed with a chest radiograph. Treatment includes needle thoracotomy and chest tube placement along with supportive therapy. Prevention includes avoidance of positive pressure ventilation whenever possible (use manual ventilation instead) and discontinuation of nitrous oxide (N_2O). See also "Pneumothorax" and "Tension Pneumothorax" sections under "Clinical Complications During Pneumoperitoneum," later.

Hypothermia

Perioperative hypothermia and shivering are risks for all patients, especially for older and sicker patients. A 0.5°C drop in body core temperature stimulates the hypothalamus, which initiates shivering. Abnormally large muscle masses are involved in this exothermic reaction to reestablish lost body heat. Shivering increases oxygen consumption by 100% to 400%, with potential deleterious effects; in that respect, shivering mimics a grand mal seizure.[44] The cardiovascular system may be affected with bradycardia, atrial fibrillation, ventricular arrhythmias, and even cardiac arrest.[45,46] It is known that hypothermia prolongs QTC on EKG, which in a familial form of long QT syndrome may cause torsade de pointes. Patients feel extremely cold and uncomfortable and may experience confusion, delayed awakening, brain infarct, and even brain death.[47] The musculoskeletal system will show slowness, rigidity, and cramps, among other effects. Surgical blood loss will be increased.[48,49]

Several pharmacologic treatments for shivering (e.g., meperidine 25–50 mg IV or chlorpromazine 2–5 mg IV) work within a few minutes, and as soon as shivering stops, patients suddenly feel comfortable and warm.[50] Treatment for hypothermia includes body warming and fluid warming. Fast rewarming is dangerous because it rapidly increases oxygen consumption, on a temporary basis (100–200%).

Best prevention for hypothermia includes using a fluid warmer (for all IVs), a body warmer (e.g., Bair Hugger, Bair Paws gown) for all cases, warm irrigation fluids, warm ORs, and shorter surgical procedures. Since most of the heat loss during surgery occurs in the first 10 minutes of the procedure, prewarming patients while waiting for surgery and continuing warming in the OR are important. Tetraplegic and paraplegic patients are at highest risk for prolonged hypothermia. They must be warmed throughout the entire surgery and recovery. They cannot shiver and are vasodilated at all times; therefore, they will take an extremely long time to rewarm postoperatively.

Hyperkalemic Cardiac Arrest

Patients with spinal cord injury (paraplegics and tetraplegics who frequently undergo endourologic procedures) and those who are bedridden long term run the risk of hyperkalemic cardiac arrest secondary to succinylcholine (SCH) administration, which is used to facilitate intubation. This occurs due to massive extrajunctional proliferation of SCH receptors of the neuromuscular junction in this subset of patients and also can be secondary to massive burns, brain and peripheral nerve injury, or muscle atrophies or dystrophies.

In these patients, SCH produces intense muscle fasciculations with massive release of intracellular potassium and cardiac arrest. Avoiding SCH or using regional anesthesia prevents this complication. If muscle relaxants are needed for the procedure, a safer choice is a nondepolarizer (e.g., atracurium, rocuronium, etc.).

Autonomic Hyperreflexia

Autonomic hyperreflexia is characterized by an uncontrolled sympathetic response secondary to a precipitant, due to loss in descending inhibition from higher centers and due to alterations in connections within the distal spinal cord. Autonomic hyperreflexia usually occurs in patients with spinal cord injuries at the T6 level and above; it occurs in 50% to 70% of this patient population. Signs and symptoms of autonomic hyperreflexia are caused by the vasoconstriction and sympathetic response below the level of the spinal cord lesion and by the compensatory parasympathetic response above the level of the lesion.

Major symptoms include hypertension (defined as a minimum increase of 20 mm Hg above baseline), headache, sweating, flushing or pallor above the level of the lesion, and bradycardia. Other less common signs include pupillary changes, Horner syndrome, nausea, and anxiety. The most common precipitants of autonomic hyperreflexia involve the urinary tract. Importantly, bladder distention (mostly urodynamic studies) has been shown to account for up to 85% of cases. Urinary tract infections (UTIs), genital stimulation, urologic procedures, and even catheterization can also elicit a response.[51] When autonomic hyperreflexia is suspected, treatment should begin immediately, before serious complications result, such as intracranial hypertension, seizures, or intracranial hemorrhage. Removal of the stimulus and pharmacologic treatment of the hypertension should be done immediately. A short acting α-blocker (e.g., phentolamine 5–30 mg IV in divided boluses) is generally effective in normalizing BP.

Preventing autonomic hyperreflexia begins by identifying those patients at risk (T6 and above spinal cord lesions) and maintaining a high index of suspicion. For the urologist, measures that reduce the incidence of bladder distention (e.g., anticholinergic, intermittent catheterization) may reduce the incidence of attacks.

For these patients, spinal anesthesia is the anesthesia technique of choice, especially for urologic procedures, because it prevents most cases of autonomic hyperreflexia, avoids the need for general anesthesia, and provides excellent cardiovascular stability.[52] The slight disadvantage of spinal anesthesia is that it may be difficult to reliably determine the level of blockade. General anesthesia also has been used successfully and autonomic hyperreflexia avoided as long as deep anesthesia is maintained. However, these patients have a host of other medical issues associated with their spinal cord injury (e.g., immobility, muscle wasting, respiratory issues, thermoregulation problems), which may increase the risk of general anesthesia. Epidural and MAC (sedation, local anesthetic infiltration) have been reported as less successful in preventing autonomic hyperreflexia when compared with spinal and general anesthesia.

Malignant Hyperthermia

Malignant hyperthermia (MH) is an uncommon pharmacogenetic clinical syndrome of hypermetabolism triggered by specific anesthetic agents. MH is an inherited disorder that occurs in 1 in 10,000 to 1 in 250,000 patients.[53]

MH susceptibility is thought to be due to a defective Ca^{++} channel located on the sarcoplasmic reticulum (SR). This channel is called the ryanodine receptor (RyR1). Various environmental and pharmacogenetic conditions may produce an uncontrolled massive release of Ca^{++} ions from the SR initiating a hypermetabolic state. About 70% of MH susceptible families may carry one of the 34 known mutations for MH.[54] There are about 400 variants connected with the *RyR1* gene.

All inhalational anesthetics, except N_2O, can trigger MH. SCH is a very frequent trigger. Safe anesthetic agents include N_2O, barbiturates/IV anesthetics, all narcotics, and all antianxiety medications. MH can begin during administration of anesthetic agents, or it may occur postoperatively.

Testing for susceptible patients, the so-called *in vitro* caffeine-halothane contracture test (CHCT), is done on freshly collected muscle biopsy specimens. A complete list of testing center locations in North America is available from the Malignant Hyperthermia Association of the United States (MHAUS) at www.mhaus.org.

Predisposing diseases include certain muscle disorders, such as central core disease, Duchenne or Becker muscular dystrophies, specific types of myotonia, and hyper- or hypokalemic paralyses.[53]

Special clinical syndromes have been grouped as masseter muscle rigidity (a sustained contracture of the jaw muscles after SCH administration, which may or may not progress to full MH), sudden unexpected cardiac arrest (especially soon after the use of SCH), and myopathies (muscle rigidity and/or hyperthermia – if hyperkalemia is successfully treated, the outcome may be good). These syndromes may occur alone or in the context of fully developed MH.

To diagnose MH, one should consider both clinical presentation and laboratory data. One of the most consistent clinical indicators is an unanticipated increase (tripling or quadrupling) of $ETCO_2$ when minute ventilation is normal. Sudden unexpected cardiac arrest may occur, especially in boys and young men (aged 5–15 years), and hyperkalemia should be suspected. Unexpected tachycardia is an early symptom, as are tachypnea and masseter spasm. Respiratory and metabolic acidosis usually indicate advanced or fulminant MH (late clinical development). Body rigidity is a specific sign of MH in patients under general anesthesia. Core body temperature elevation is often a late sign of MH. Postoperative rhabdomyolysis and acute myoglobinuric renal failure are usually later events. There is a 25% MH recurrence rate in the postoperative period, thus patients should be watched carefully after any initial MH event.[55]

Differential diagnoses include thyroid storm, sepsis, pheochromocytoma, and intraoperative overheating. Additionally, outside the OR, a similar syndrome may be caused by a cocaine overdose or a subarachnoid injection of ionic contrast materials.

Other conditions may mimic MH, including serotonin syndrome, 3,4-methylenedioxy-methamphetamine (MDMA) hyperthermic syndrome caused by overdose (psychotropes and haloperidol), and sudden hyperkalemic cardiac arrest (HCA). Hyperkalemic cardiac arrest may occur with alarming frequency in Duchenne's muscular dystrophy, a condition found in 1/3500 live births. Since Duchenne's symptomatology frequently occurs for the first time as late as 5–8 years old, use of SCH should be avoided in all young children.[56]

Treatment begins by immediately discontinuing the triggering agent. Hyperventilate with 100% oxygen. Treat with IV 2.5 mg/kg dantrolene sodium (because this solution does not have significant side effects, it should be used for all cases in which MH is suspected) or the newly developed alternative, high-potency dantrolene (Ryanodex 250 mg per ampule). Treat acidosis with bicarbonate; treat hyperkalemia with glucose, insulin, and calcium; and treat hyperthermia with cooling (nasogastric lavage, rectal lavage, intraperitoneal lavage, surface cooling – to end point of 38°C). Avoid calcium channel blockers (use other antiarrhythmics). Carefully monitor serum potassium and measure CPK (a good measure of muscle destruction) every 6 hours until it is decreased (though in severe MH, high CPK might last for 2 weeks). Follow the coagulation profile because disseminated intravascular coagulation may occur. Check serial ABG, electrolytes, blood, and urine myoglobin.

Prevention begins by identifying patients at risk of MH through a positive history or previous testing. Patients with known or suspected MH who need surgery can be safely operated on by using a nontriggering anesthesia technique (total avoidance of triggering agents) and a mandatory fresh oxygen (O^2) flushing of the anesthesia circuit for a minimum 60 minutes preoperatively (in order to eliminate any traces of inhalational agents from the rubber or silicone gaskets found on the newer anesthesia machines). ASA recommends measuring core body temperature in all anesthesia cases lasting >30 minutes. It is recommended that a full complement of fresh dantrolene ampules and chilled IV fluids, along with full resuscitative medications, be readily available at all times in the OR. Patients with a history of exercise and/or emotional stress-induced fevers, and those with severe statin myopathy should be tested for MH preoperatively. The use of isovolumetric contraction time (IVCT) in conjunction with genetic studies improves the chance of diagnosing true MH-positive individuals.

Postoperative Nausea and Vomiting

If untreated, up to 30% of all surgical patients will have PONV after general anesthesia with inhalational anesthetics, whereas high-risk patients will have an incidence up to 80%. Patients with an increased incidence of PONV tend to be young children; women; or patients with preoperative pain and anxiety, delayed gastric emptying, and, most importantly, a positive history of motion sickness and previous PONV. Anesthesia risk factors for PONV include dehydration, general anesthesia with inhalational anesthetics, anesthesia lasting longer than 3 hours, and the use of N_2O, narcotics, sedatives (e.g., ketamine, etomidate), neostigmine, and residual air in the stomach secondary to mask ventilation. Surgical factors that increase the likelihood of PONV include laparoscopic surgery, hernia repair, and orchiopexy. Postoperative risks include sudden motion, pain, and early fluid intake.

Various antiemetic medications are used to treat nausea and vomiting.[57] One group of antiemetics works by antagonizing neurotransmitters at various receptor sites (e.g., dopamine, histamine, serotonin, or cholinergic-muscarinic receptors). These include antihistamines (diphenhydramine and promethazine), butyrophenones (droperidol and haloperidol), phenothiazines (chlorpromazine and prochlorperazine), benzamides (metoclopramide), and anticholinergics (scopolamine). Another group works as specific antiserotonin (5-HT_3) antagonists (ondansetron, granisetron, and dolasetron). Dexamethasone is a corticosteroid that works through antiinflammatory and some unknown properties.

Various side effects occur after using antiemetic medications. Their most significant side effect is sedation.

As prophylaxis for PONV, dexamethasone combined with an antiserotonin antagonist proves to be one of the most efficient regimens, if used at induction of general anesthesia. For treatment of PONV, combinations of antiemetics seem to be more efficient (through their additive effect) than single medications. In our experience, however, when everything else fails, one of the best rescue medications is haloperidol 1.0 mg to 1.5 mg used intramuscularly (an IV dose is too short acting), which provides >15 hours of intense antiemetic effect without excessive sedation or any hallucinations.

The most effective ways to prevent PONV are using a propofol-based TIVA (see next section) and preferentially avoiding inhalational anesthetics, N_2O (which causes a 30% increase in PONV), and unnecessary sedatives. Also, gastric air should be suctioned out. Propofol TIVA proves especially useful in patients at higher risk for PONV (those with a history of motion sickness or previous PONV).

Propofol Total Intravenous Anesthesia (Propofol TIVA). Propofol TIVA is a widely used general anesthetic technique, using a variable mixture of propofol drip and fentanyl. It can be administered with the patient breathing spontaneously or with the patient muscle relaxed and mechanically ventilated. In either TIVA technique, no N_2O, benzodiazepines, or other sedative medications are needed (bispectral index [BIS] monitor tested), and these should be avoided because they tend to produce PONV, delay awakening, and prolong recovery. Propofol TIVA predictably provides a well-anesthetized patient with no operative recall, who is easy to wake up, and who has satisfactory postoperative analgesia, no memory loss, and no PONV.

For patients with a history of hypersensitive (hyperreactive) airway such as asthma (even if childhood asthma), smoking, or obesity or patients with recent upper respiratory infections (within the past 6–8 weeks), chronic bronchitis, or eczema, low concentrations of inhalational agents (e.g., 0.2–0.4% sevoflurane) can be safely added (for deeper anesthesia level and bronchodilation) to the TIVA. The same regimen should be used for any obese patient or intubated patient. Adding low concentration inhalational agents does not diminish the potent antiPONV qualities of the propofol/fentanyl TIVA.

Positioning-related Complications

Urologic surgeries require the patient to be in specific positions (e.g., supine, prone, lithotomy, semilateral or lateral position), which can cause inadvertent nerve injury. Most nerve injuries involve the ulnar nerve (28%), brachial plexus (20%), lumbosacral nerve roots (16%), and the spinal cord (13%).[58] Nerve injuries usually occur as a result of compression or stretching of the nerve.

With patients in the supine position, the most commonly injured nerve is the ulnar nerve, regardless of whether the patient has both arms tucked at his or her side or out on armboards. With patients in the lithotomy position, sciatic, femoral, and peroneal nerves are at increased risk for injury. In the semi-lateral and lateral position, the brachial plexus is at increased risk. Meticulous attention must be paid to the positioning of a patient, ensuring that he or she is not stretched beyond the physiologic range, and padding all the pressure points to reduce the incidence of nerve injury.

According to the ASA practice advisory for prevention of perioperative peripheral neuropathies,[59] arm abduction should be limited to 90 degrees in supine patients. Arms also should be positioned to decrease pressure on the postcondylar groove (ulnar nerve) and the spiral groove of the humerus (radial nerve). A neutral forearm position or supination of the arms with proper padding should meet this recommendation.

For lower extremity positioning, excessive stretching of the hamstring muscle group beyond a comfortable range must be avoided (especially in lithotomy position), as this may cause sciatic neuropathy. Prolonged pressure on the peroneal nerve at the fibular head should be avoided by using proper padding (especially in lithotomy position). Neither flexion nor extension of the hip has been shown to increase the risk of femoral neuropathy, although it is advised that excessive flexion or extension be avoided.

Preventing peripheral neuropathies begins in the preoperative phase. Certain patient characteristics have been shown to be associated with perioperative neuropathies, including smoking, diabetes, vascular disease, arthritis, and extremes of body weight and age. Preoperatively, any preexisting neuropathies should be identified during the initial history and physical examination, and the patient's normal comfortable range of motion should be determined. Intraoperatively, patient positioning and padding should be checked periodically. Postoperatively, patients should be watched for early signs of any nerve injury and appropriate steps taken, including obtaining neurologist consultation if necessary.

For more specific complications of patient positioning in laparoscopic/robotic cases, see "Complications of Patient Positioning in Robotic Surgery," later.

COMPLICATIONS DURING REGIONAL ANESTHESIA

A preponderance of outcome data suggests that regional anesthesia improves patient morbidity and mortality,[60] as compared with general anesthesia. Also, regional anesthesia was found to reduce overall mortality by approximately 30%. Regional anesthesia decreased the odds of deep venous thrombosis by 44%, PE by 55%, transfusion by 50%, pneumonia by 39%, respiratory depression by 59%, MI by 33%, and renal failure by 43%, thus greatly reducing overall morbidity as well. The benefits of regional anesthesia include the following:[60]

- Attenuation of the body's stress response perioperatively (preserves cardiovascular function)
- Preservation of respiratory function and decrease in pulmonary complications
- Faster recovery of postoperative GI function
- Decrease in intraoperative blood loss
- Decrease in postoperative hypercoagulability
- Preservation of perioperative immune function
- Superior postoperative analgesia compared to systemic opiates
- Decreased length of stay in the postanesthesia care unit (PACU) due to adequate pain control
- Increase in patient satisfaction

Contraindications for regional anesthesia include patient refusal, cardiac outflow tract obstruction (as in IHSS and aortic stenosis), the anticoagulated patient (when INR ≥1.4), skin infections, serious previous neurologic deficiencies, hypotension, allergy to local anesthetic, sepsis, and hemorrhagic shock.

Regional anesthesia can be divided into two categories: neuraxial anesthesia (e.g., spinal, epidural, combined spinal/epidural) and peripheral nerve block anesthesia (e.g., pudendal, penile, paravertebral).

Neuraxial anesthesia deposits a local anesthetic within the subarachnoid (spinal) or epidural space. This produces sympathetic block (vasodilation), sensory block (painlessness), and motor block (muscle relaxation), with separate corresponding levels, each producing distinctive physiologic changes.

The sympathetic block results in vasodilation, with an increase in volume of the capacitance vessels, causing a decrease in cardiac preload and secondary hypotension. This undesirable hypotension can be abrupt and severe, directly proportional to the degree of sympathetic denervation, and it must be treated early and aggressively with vasopressors, fluids, and head-down position (thus increasing cardiac preload). The sympathetic denervation may involve the entire lower extremities, the pelvis, or the thoracoabdominal cavity, depending on the height of the sympathetic level achieved. The sympathectomy slowly wears off throughout the surgery and outlasts the sensory block by about 3 hours.

The sensory blockade renders the patient insensitive up to a certain level, which can be manipulated in various ways in order to achieve painlessness for the entire dermatomal distribution of the surgical procedure and for the duration of surgery and recovery.

The motor blockade also can be manipulated at will to produce full muscle relaxation extending from the lower extremities all the way up to the thoracic wall, depending on the type of surgery performed. For surgical anesthesia, solid sensory and motor denervation are needed, whereas for postoperative analgesia only sensory block is required.

Spinal Anesthesia

Spinal anesthesia is achieved by injecting small amounts of various local anesthetics below the L1 spinal level directly into the cerebrospinal fluid (CSF) through a fine needle inserted beyond the arachnoid membrane. A sensory dermatomal level is obtained. The sympathectomy (vasodilation) level will be 3 segments higher than the sensory level. The motor block is about two dermatomal levels lower than the sensory level. Duration of the spinal block depends on the type, dose, and baricity of the local anesthetic used; it also depends on patient positioning. The major side effect of spinal anesthesia is drop in BP, proportionate to the level of sympathectomy (vasodilation). For best treatment of this side effect, see "Further Prevention of Regional Anesthesia Complications," later.

The following important complications may occur with spinal anesthesia.

Postdural Puncture Headache. Postdural puncture headache (PDPH) is a headache that may occur 24 to 48 hours after spinal anesthesia or unintentional dural puncture (UDP) during epidural anesthesia. It is thought to be due to a continuous leak of CSF through the spinal puncture hole, decompressing the subarachnoid space with secondary stretching of the cranial nerves. PDPH has two specific characteristics: It is frontal and positional. It typically appears as a throbbing frontal headache (of variable intensity). Its main positional characteristic is used as a test. When the patient is lying in bed, he or she may have no headache at all. However, when the patient sits up or walks, a throbbing frontal headache will occur, which disappears when the patient lies down again. In severe cases, even a slight lift of the head from the horizontal position elicits the headache. This positional test differentiates PDPH from sagittal sinus thrombosis, which produces a continuous throbbing headache in any position.

Associated symptoms of PDPH include neck ache or stiff neck (57%), upper back ache (35%), nausea (22%), and visual and auditory disturbances. If untreated, PDPH spontaneously resolves within 1 to 6 weeks, but it is very distressing to patients.

Conservative treatment relies on hydration, caffeine (cerebral vasoconstrictor), sumatriptan succinate (serotonin type 1d receptor agonist, a powerful cerebral vasoconstrictor), and adrenocorticotropic hormone (a controversial treatment, which works through increased CSF production and/or β-endorphin release). Some recent work points to more effectiveness when using neuraxial morphine[61] or systemic cosyntropin in cases of UDP.[62,63]

Invasive treatments include epidural blood patch (the gold standard), used only for unrelenting symptomatology.[64] This consists of injecting 10 to 15 mL autologous blood into the patient's epidural space. PDPH disappears immediately in 85% of such cases, and recurrence is rare. There are insufficient data to support the prophylactic use of epidural blood patch after UDP.[65] A recent study suggests that a greater occipital nerve block with added dexamethasone might be effective treatment for PDPH.[66]

Cauda Equina Syndrome/Transient Neurologic Syndrome. Cauda equina syndrome (CES) is a clinical representation of local anesthetic neurotoxicity. It can present as varying degrees of pain or neurologic deficit limited to the lower extremities, and it can create functional deficiencies (e.g., urinary and fecal incontinence). It may present with

transient symptomatology, or it may evolve into permanent neurologic lesions with permanent loss of function. Permanent CES is very rare.

All local anesthetics are potentially neurotoxic in high doses. CES may be caused by maldistribution, high concentration, and/or high and repetitive doses of local anesthetics. See "Local Anesthetic Systemic Toxicity," later.

Transient neurologic syndrome (TNS) is another clinical representation of local anesthetic neurotoxicity. TNS has been described in conjunction with continuous spinal anesthesia, where overly frequent topoff reinjections of the same local anesthetic through an indwelling subarachnoid catheter may cause toxicity. TNS also may appear on rare occasions after spinal administration of single doses of lidocaine, mepivacaine, bupivacaine, or any other spinal anesthetic, if used in excessive doses. However, in our experience, following thousands of subarachnoid meperidine blocks, TNS has not occurred. We strongly recommend using meperidine in regular doses of 40 to 50 mg in all cases. See "Further Prevention of Regional Anesthesia Complications," later.

Epidural Anesthesia

Epidural anesthesia is achieved by injecting local anesthetic into the epidural space, which is located between the dura mater and the yellow ligament (ligamentum flavum). Consequently, a sensory dermatomal block is obtained, associated with a sympathectomy (vasodilation) three to six dermatomal segments higher. A motor block is also obtained. In clinical practice, epidural anesthesia can be obtained with a single injection or through an epidural catheter used for reinjection with local anesthetic in order to prolong surgical anesthesia or to provide postoperative pain relief. The major side effect of epidural anesthesia is hypotension, proportionate to the level of sympathectomy (vasodilation). The onset of this hypotension is slower than the hypotension associated with spinal anesthesia. For best prevention or treatment of this side effect, see the use of combined IV/IM ephedrine in "Further Prevention of Regional Anesthesia Complications," later.

The following complications may occur with epidural anesthesia.

Inadvertent Subarachnoid Injection. Inadvertent subarachnoid injection is an accidental local anesthetic injection into the subarachnoid space (CSF). This occurs when the epidural needle accidentally penetrates the dura mater and arachnoid membranes and ends up in the subarachnoid space. Epidural anesthesia requires much higher local anesthetic volumes than spinal anesthesia (~1.5 mL per dermatomal segment blocked); if some of this high-volume anesthetic ends up in the subarachnoid space, it will create undesirably high levels of subarachnoid block (total spinal). This will cause widespread sympathectomy and vasodilation, with a sudden drop in BP and cardiac output, leading to a clinical picture of shock, often rapidly progressing to respiratory and cardiovascular arrest.

As a first measure, the patient is immediately placed in the Trendelenburg position in order to increase preload to the heart. Treatment then is geared toward cardiovascular and respiratory support.

Prevention includes keeping patients awake and conversant, using a subarachnoid test (injecting small fractionate doses of local anesthetic), and slowly raising the dermatomal sensory level of anesthesia with frequent testing (cold or pinprick test).

Inadvertent Intravascular Injection. Inadvertent intravascular injection is unintended injection of a large dose of local anesthetic into a blood vessel within the epidural space. This may occur during a single injection through the epidural needle or following even small fractionate doses of local anesthetic through an epidural catheter. Local anesthetic intravascular toxicity may occur with the following symptoms, usually appearing in a clinically predictable sequence: tinnitus, perioral numbness, dizziness, fainting, drop in BP, bradycardia, seizures, coma, and death.

Treatment is to immediately stop injecting the local anesthetic and, in cases of seizure or cardiovascular collapse, use sedatives and cardiovascular support measures. In cases of clinical shock with cardiorespiratory arrest, cardiopulmonary resuscitation must be administered. Recent evidence-based practice advocates emergency treatment with lipid emulsion (Intralipid 20%, a 100% long-chain triglyceride emulsion), which is thought to function as a pharmacologic "lipid sink" to eliminate the highly liposoluble local anesthetics.[67–70] See also "Local Anesthetic Systemic Toxicity," later.

Prevention starts with the correct placement of the epidural catheter. Then the epidural catheter is tested with an IV testing dose using small, nonseizure producing, tracer-laced (e.g., epinephrine) local anesthetics while looking for tachycardia on ECG. It is essential to inject slowly, keeping the patient conversant and asking for the presence of early symptoms of local anesthetic intravascular toxicity (i.e., tinnitus, perioral numbness, dizziness). If these symptoms appear, immediately stop the injection and assume toxicity. The use of benzodiazepines at this point will prevent seizures; however, these drugs will not prevent the cardiovascular collapse secondary to a massive intravascular injection. Use basic monitoring (ECG, BP cuff, pulse oximetry, $ETCO_2$) for the entire epidural and surgical procedure in order to observe any other symptoms of inadvertent intravascular injection (e.g., drop in BP, drop in arterial saturation, bradycardia).

Maintain general awareness of this potential complication throughout the case. Even if the local anesthetic is injected properly (negative IV test), if massive toxic doses accumulate over time, a similar delayed clinical picture may occur. The anesthesiologist must not trespass into the generally acknowledged toxic doses of each specific local anesthetic. See also "Local Anesthetic Systemic Toxicity," later.

Combined Spinal/Epidural Anesthesia

Combined spinal/epidural (CSE) anesthesia blends the advantages of both types of anesthesia. Classically, the spinal anesthesia component, with its early onset and dense block, is used for surgical anesthesia; this might be sufficient for the entire surgery. The epidural catheter, however, may be accessed for additional anesthesia during surgery if, at any time, the spinal anesthesia wears off. The same

epidural catheter also can be used for prolonged postoperative analgesia.

Complications can arise from either the spinal or the epidural component of the technique. Prevention of most potential CSE complications is identical to the separate spinal and epidural preventive measures.

Local Anesthetic Systemic Toxicity

Local anesthetic systemic toxicity may occur in two ways: massive reabsorption after tissue injection or secondary to inadvertent intravascular injection. If the quantity (in milligrams) of the local anesthetic injected exceeds certain toxic peak levels, the following symptoms may be produced:

1. *Central nervous system (CNS) excitability/depression:* Tinnitus, perioral numbness, dizziness, confusion, seizures, coma, death
2. *Cardiovascular effect:* Peripheral vasodilation with hypotension, heart block, bradycardia, ventricular tachycardia, asystole, cardiovascular collapse
3. *Respiratory effect:* Respiratory depression due to direct local anesthetic effect and/or secondary to CNS and cardiovascular effects
4. *Methemoglobinemia:* Central cyanosis refractory to supplemental oxygen administration appears at a methemoglobin level >15%. At 50% to 60% methemoglobinemia may produce confusion, arrhythmias, hemodynamic instability, and seizures, leading to death. Chocolate-colored blood that keeps its color despite exposure to air is diagnostic. Methemoglobinemia can occur after large doses of benzocaine topical administration and absorption (usually used for various endoscopic procedures). Also it may occur when large doses of prilocaine (>600 mg) are administered. (Prilocaine is no longer available for use as a local anesthetic.)[71]

There are two general categories of local anesthetics: esters and amides. Esters – tetracaine, procaine, 2-chloroprocaine, and benzocaine – are metabolized in the body by the natural esterases, which limit and terminate their inherent toxicity. The amides – bupivacaine, levobupivacaine, ropivacaine – are metabolized in the liver, a lengthier process, thus making these local anesthetics available free in the blood stream for a longer time, as well as prolonging their potential toxicity.

Treatment. Treatment depends on the severity of the event. CNS excitability can be treated with sedatives such as benzodiazepines. The respiratory and cardiovascular depressant effects should be addressed by supportive measures. Severe methemoglobinemia is treated by using 1 mg/kg IV methylene blue.

IV lipid emulsion (Intralipid 20%, a 100% long-chain triglyceride emulsion) has been used successfully to bind and quickly remove the highly liposoluble local anesthetics from the intravascular system. There are numerous clinical reports of life-saving rapid reversal of major local anesthetic toxic symptomatology.[72–75] However, reversing the toxic effects of less liposoluble local anesthetics (e.g., ropivacaine and others) with lipid emulsion is more controversial.[70] It is recommended that Intralipid 20% should be used as an initial bolus of 1.5 mL/kg followed by an IV infusion of 0.25 mL/kg/minute. If adequate circulation has not been restored, the bolus should be repeated twice at 5 minute intervals with an increased infusion rate of 0.5 mL/kg/minute.[70,76]

Prevention. The overall injected quantity (in milligrams) of local anesthetic always must be kept below the toxic dose. There are various ways to estimate the toxic dose of a given local anesthetic. Clinically useful and generally acknowledged local anesthetic toxic doses (when used with epinephrine) are tetracaine 1.5 mg/kg, bupivacaine 3 mg/kg, ropivacaine 3 mg/kg, lidocaine 7 mg/kg, mepivacaine 7 mg/kg, procaine 20 mg/kg, and 2-chloroprocaine 20 mg/kg. Maintain constant vigilance during and after local anesthetic injection. Resuscitative equipment and medications must be available at all times. Monitor patients fully whenever local anesthetics are injected. When infiltrating tissues, constantly move the needle while injecting, and whenever the needle stops, before injecting, apply 90-degree double aspirations to make sure the needle tip is not inadvertently introduced into a blood vessel. Inject small fractionate doses when performing nerve blocks. Whenever possible, add a tracer substance (e.g., epinephrine) to diminish tissue reabsorption of the local anesthetic and also to provide an early sign (tachycardia) of inadvertent intravascular injection of the local anesthetic. Use of ultrasound guidance aids visualization and increases the accuracy and safety of nerve blocks.

SPINAL HEMATOMA

Bleeding associated with neuraxial blockade is a rare complication, occurring in an estimated 1 in 220,000 for spinal anesthesia and in <1 in 150,000 for epidural anesthesia.[77] Spinal hematoma may occur in patients with known or unknown coagulopathies and in patients who may be anticoagulated for various medical or surgical reasons.

Symptoms include progression of the existing sensory or motor block (68%), bladder or bowel dysfunction (8%), and pain of radicular nature.[78] Whenever spinal hematoma is suspected, a computed tomography (CT) or magnetic resonance imaging (MRI) scan is diagnostic.

If the hematoma is symptomatic, it should be surgically evacuated as soon as possible. If possible, the anticoagulant involved also should be discontinued.

Preventing spinal hematoma requires judicious perioperative planning and good communication among the urologist, anesthesiologist, cardiologist/internist, and pain clinic staff. Nonsteroidal antiinflammatory drugs (NSAIDs) do not seem to pose a serious risk, either on insertion or removal of the neuraxial needle or catheter.[79]

When subcutaneous unfractionated heparin is used, there are no added significant risks on insertion (needling) or epidural catheter removal; however, it is recommended to wait 1 hour post catheter removal before resuming anticoagulation.

When IV unfractionated heparin is used, however, a delay of 2–4 hours is advised before insertion and a delay of 1 hour after insertion before resuming anticoagulation; an additional delay of 2–4 hours is advised before catheter removal and a delay of 1 hour after catheter removal before resuming anticoagulation.

When low-molecular-weight heparin (LMWH) is used, waiting 10–12 hours before catheter insertion is recommended, and >2 hours after insertion before resuming anticoagulation; waiting 10–12 hours before catheter removal is also recommended and >2 hours after catheter removal before resuming anticoagulation. The American Society of Regional Anesthesia recommends the removal of indwelling epidural catheters before starting LMWH.

When warfarin is used for thromboprophylaxis, the INR should be allowed to normalize to ≤1.4 preoperatively.[77] For patients with drug-eluting cardiac stents, there is a specific "bridging" protocol, which recommends that patients continue their antiplatelet medication.[80,81] The American Society of Regional Anesthesia and Pain Medicine publishes highly specific evidence-based guidelines for the management of patients receiving antithrombotic or thrombolytic therapy.[82]

FURTHER PREVENTION OF REGIONAL ANESTHESIA COMPLICATIONS

Meperidine Spinal Anesthesia

In our practice, we use regional anesthesia extensively for a large number of urologic procedures. Judicious use of meperidine spinal anesthesia prevents many major and minor anesthetic complications and provides superior long-lasting postoperative pain relief.

We have perfected a technique over the past several decades in which regular doses or minidoses of meperidine have been used without any respiratory depressant effect or otherwise deleterious side effects in thousands of ASA III–IV patients. We have used this regimen with great success in a wide variety of urologic procedures, ranging from cystoscopy to long TURPs, procedures for female and male incontinence, radical retropubic prostatectomy, and endourology procedures, including transurethral and/or percutaneous lithotripsy.

Meperidine has a fast onset and, when used alone, provides a deep sensory and motor block completely resembling plain lidocaine and/or mepivacaine spinal (50 mg doses yield a similar T6 sensory level, which covers ~1.5 hours of surgical anesthesia). Subarachnoid meperidine is the only short-acting narcotic with local anesthetic properties that provides 8 to 12 hours of postoperative analgesia. In the PACU, patients who received meperidine during surgery are completely awake, have a clear sensorium, are recovered fully from the initial motor block, and do not require pain medications.

As a rare side effect, itchiness occurs in <1% of cases. If itchiness becomes intense, it is treated with naloxone 40 µg IV, followed by naloxone 80 to 100 µg IM for prolonged effect.

Meperidine does not increase the risk of spinal headache (we have observed 0% in our patient population). Meperidine does not produce TNS as do the other local anesthetics.

Meperidine may be used alone or in combinations. We add minidoses of long-acting local anesthetics (bupivacaine, pontocaine) in order to prolong meperidine anesthesia during longer surgeries. This allows great versatility in matching a spinal anesthesia regimen to the length of a particular surgical procedure, so that the motor blockade will wear off very soon after the conclusion of surgery while still providing very long postoperative analgesia.

Meperidine can provide the spinal component of the CSE technique used in extra-long cases where the epidural catheter may be kept in place for several days for prolonged postoperative analgesia.

Combined Intravenous and Intramuscular Ephedrine for Cardiovascular Stability

In order to counteract the potential drop in BP secondary to any spinal anesthesia, we use ephedrine prophylactically immediately following spinal injection, as 5 mg IV bolus, with simultaneous IM injection of 25 mg to 40 mg (depending on patient's size). The IV dose starts working within a minute, without producing undue tachycardia, and lasts up to 10 minutes. The IM dose becomes effective within 10 minutes and works for 2.5 hours (using the muscle as a depot), with only minor increases in BP or heart rate (<10%), thus ensuring a continuum of BP support. This IV/IM regimen may be safely repeated several times, every 2.5 hours in longer procedures.

If given early enough, at the onset of sympathectomy secondary to spinal administration, this ephedrine regimen will always maintain the patient's original heart rate and BP, independent of the actual hydration status. This allows ample time to rehydrate the patient. Thus, a completely stable cardiovascular status is assured for the length of the case and recovery. This ephedrine regimen confers great cardiovascular stability to spinal anesthesia, making it an extremely attractive choice for all patients, and especially older and sicker ASA III–IV patients.

The combined IV/IM ephedrine also is useful to maintain BP in early hemorrhagic shock until the patient is rehydrated to euvolemia (crystalloids, colloids, blood), and to counteract orthostatic hypotension in the PACU (after rehydration fails).

Nerve Blocks in Urology

Nerve blocks offer a safe anesthetic approach to a multitude of urologic procedures and a rapid painless recovery for all patients. These blocks prove to be especially safe and useful in old and sick ASA III–IV patients because these blocks eliminate the risks and complications that general and regional anesthesia cause while providing a stressless operative and postoperative course (pain free, no PONV, clear postoperative mentation).

Contraindications to these nerve blocks include patient refusal, anticoagulation, allergy to the local anesthetic, and local infection.

Pudendal block and penile block are the nerve blocks most frequently used in hospital-based urologic surgery.

PUDENDAL NERVE BLOCK

Pudendal nerve block may be used in all superficial male and female perineal surgeries; male and female lower urinary reconstructive procedures; sling procedures for

incontinence; rectal and urinary sphincter procedures; and procedures on the penis, clitoris, scrotum, and labia majora. The pudendal nerve block can be used in conjunction with a short spinal anesthesia, general anesthesia, or continuous propofol/fentanyl TIVA.

The pudendal nerve innervates the perineum, the anal and urethral sphincters, the penis, and the clitoris. A number of male and female urologic procedures depend on knowledge of pudendal innervation, including anal and stress incontinence surgeries via suprapubic, perineal, or vaginal approaches, and pudendal canal decompression for pudendal canal syndrome and pudendal artery syndrome (with erectile dysfunction).[83]

The sacral plexus gives off the pudendal nerve by using the S_2, S_3, and S_4 anterior rami. The pudendal nerve roots emerge from the anterior sacral foramen. The pudendal nerve contains autonomic and motor nerve fibers together, making it a mixed nerve.

Out of the pudendal canal, the pudendal nerve gives off three terminal branches: the inferior rectal nerve, the perineal nerve, and the dorsal nerve of penis or dorsal nerve of clitoris.[84]

The inferior rectal nerve supplies the external anal sphincter, the mucous membrane, and the lower half of the perianal skin and the inner anal canal. The perineal nerve gives off deep branches to the muscles of the urogenital triangle and superficial branches to the skin of the lower labia majora and lower scrotum. The dorsal nerve of the penis or clitoris supplies sensory nerve endings to the skin surface of the clitoris and penis.

The pudendal nerve runs through three significant anatomic regions: the gluteal region, the pudendal canal, and the perineum. The course of the pudendal nerve in the area of the ischial spine is important because this is where the pudendal nerve block is placed.

There are three approaches to the pudendal nerve block:

1. Transvaginal approach
2. Midperineal approach
3. Direct percutaneous approach (Vaida method).

Transvaginal Approach

This method, often used in obstetrics, provides perineal analgesia during the third stage of delivery, when the presenting part of the newborn is visibly bulging the perineum. It is also useful in female urologic surgery.

The block is done with the patient in the lithotomy position. Palpate with the left hand (5–6 cm intravaginally) the left ischial spine through the left lateral vaginal wall. Affix the tip of an Iowa Trumpet between the palpating fingers and the tip of the ischial spine. Pass a long injecting needle through the trumpet and through the vaginal wall until it punctures the sacrospinous ligament and advances another 1 cm. Perform two 90-degree safety aspirations, and, if there is no blood return, inject 5–8 mL local anesthetic.

Repeat the same exact technique on the patient's right side, using the right hand for vaginal examination and the left hand for the aspiration-injection sequence. The sensory block obtained between the anus and clitoris can be ascertained by pinprick testing the skin of this area. Any local anesthetic may be used, such as 3% 2-chloroprocaine (providing a 1–2 hour block), lidocaine 1.5% or 2% (providing a 2–3 hour block), bupivacaine 0.25% or 0.5% (providing a 6–8 hour block) or ropivacaine 0.5% (providing an 6–8 hour block).

Complications. Potential problems may include accidental rectal puncture, bleeding (rare), pudendal blood vessel puncture (with local anesthetic systemic toxicity), and infection (rare). Avoid injecting large volumes of local anesthetic because toxicity may occur. See "Local Anesthetic Systemic Toxicity," earlier.

Prevention. The 90-degree double safety aspiration before the injection (to ascertain that the needle tip is not in intravascular position) is essential. When the patient is in the lithotomy position, the rectum is located medial and inferior to the ischial spine; therefore the palpating hand entirely protects the rectum. Do not do any puncture until the Iowa Trumpet is firmly affixed between the palpating fingers and the ischial spine.

Midperineal Approach

The midperineal approach can be used in female and male urology cases. With the patient in the lithotomy position, the block is done midway between the rectum and the base of the penis or vagina on the midperineal line. With the area thoroughly prepared, and with the contralateral gloved index finger palpating the ipsilateral ischium, pass the injecting needle posteriorly and laterally from this point, aiming toward the ischial spines, one at a time. When the ischial spine is contacted, walk the needle off the bone, medioinferiorly, about 1 cm past the sacrospinous ligament. After two 90-degree safety aspirations (ensuring no blood return), deposit 5–8 mL local anesthetic. The reverse is applied for the other side.

Complications. Complications include accidental rectal puncture, pudendal vascular puncture (local anesthetic systemic toxicity), and infections (rare). Avoid injecting large volumes of local anesthetic because toxicity may occur. See "Local Anesthetic Systemic Toxicity," earlier.

Prevention. Rectal puncture is prevented by guiding the needle with simultaneous transrectal palpation of the ischial spine. Inadvertent puncture of blood vessels is prevented by the 90-degree double safety aspirations.

Direct Percutaneous Approach (Vaida Method)

This method is an attractive approach for male or female urology, because it is easily performed using the ischial spines as landmarks. It is done with the patient in the lithotomy position, with the entire perineum and gluteal areas thoroughly prepared with antiseptic solution. A syringe containing 10 to 16 mL local anesthetic is outfitted with a 20-gauge spinal needle. In the lithotomy position the ischial spine can be palpated easily directly through the skin about 3–4 cm lateral from the midperineal point. Through a puncture done at this level (over the ischial spine), insert the needle in a 10-degree posterolateral direction. When the needle tip contacts the ischial spine, walk it off medially, through the sacrospinous ligament, for an extra 1 cm. After two 90-degrees aspirations, deposit 5–8 mL local anesthetic. Repeat again over the other ischial spine.

Complications. The direct percutaneous approach avoids rectal injury, which is more likely in the midperineal approach, and inadvertent intravascular injection (the slight angulation keeps the injecting needle in a more medial position away from the pudendal vessels). However, infection is a potential (although rare) complication.

Prevention. Double 90-degree safety aspirations are used in order to prevent local anesthetic systemic toxicity. Thorough skin preparation is essential to prevent infections.

PENILE BLOCK

Thorough understanding of pudendal nerve anatomy is necessary to administer the penile block. Terminal branches of the pudendal nerve innervate the rectum, the perineum, the scrotum, and the penis.

Perineal Nerve

After emerging from the pudendal canal, the perineal nerve courses downward for 2–3 cm and gives rise to two terminal divisions: a lateral scrotal branch and the medial striated urethral branch.[85,86] The scrotal branch unites with the inferior rectal nerve to form the common scrotal branch, which innervates the posterior aspect of the scrotum.

Deep Dorsal Nerve of Penis

This is one of the two branches of pudendal nerve leaving the pudendal canal. It courses forward along the inferior pubic ramus, along the end of the ischiorectal fossa, into the deep perineal pouch. The nerve courses forward into the suspensory ligament of the dorsum of penis, sending terminal branches to the entire dorsum.[87] It is noteworthy that very often a well done dorsal penile block spares the anterior lower part of the penis, which is innervated by rami of the perineal branch of the pudendal nerve as well.[88] By contrast, the circumferential block done at the base of the penile shaft is a complete block of the dorsal nerve of penis and the perineal branches of the pudendal nerve, which provide sensory innervation to the mid-anterior aspect of the penis all the way up to the frenulum.[89]

Indications of Penile Block (Adults Only)

Although circumcision is performed on an estimated one in six newborn males worldwide and about 60% of newborn males in the United States,[90] adult circumcision is much less frequently performed. The usual indications for adult circumcision are social, personal, or medical, including the following: phimosis, paraphimosis, acute paraphimosis (emergency), recurrent infections such as balanitis and posthitis, or preputial neoplasms. General anesthesia, penile block, or a combination of both is used in the majority of these cases.

The penile block is always done before the surgery begins, preferably using long-acting local anesthetics (e.g., 30 mL bupivacaine 0.375% or 0.5% provides 8–15 hours analgesia). Because the penis is an organ with terminal circulation, the local anesthetic used for penile block must never contain epinephrine. See "Penile Ischemia and Necrosis," later. The block is intensely painful; therefore, it should be done under a TIVA using continuous propofol/fentanyl technique, with the patient spontaneously breathing oxygen by mask. This technique may be continued throughout the entire surgical procedure, as a light or medium sedation. See "Propofol Total Intravenous Anesthesia (Propofol TIVA)," earlier.

Penile Nerve Block Techniques

There are two accepted penile nerve block techniques that may be used separately or together. Keep in mind that a bilateral pudendal nerve block will effectively provide full sensory block of the penis.

Dorsal Penile Nerve Block. Dorsal penile nerve block[91] is done by injecting 5–8 mL local anesthetic through a 27-gauge needle, deep to Buck's fascia, where the two (left and right) dorsal nerves of the penis emerge from under the pubic bone. Inject at the 10-o'clock and 2-o'clock positions at the base of the penis, walking the needle off caudad the pubic bone and popping through Buck's fascia.

A 4–6.7% failure rate has been reported using the dorsal block alone.[89] See "Deep Dorsal Nerve of Penis," earlier. To complete the block on the upper ventral side of the penis, a subcutaneous ring block must be done at the base of the frenulum.

Circumferential Block. This is our preferred technique because it provides 100% sensory block of the penis.[91] With the penis pulled up vertically and thoroughly prepped, 15–30 mL of local anesthetic is injected subcutaneously at the very base of the penile shaft, circumferentially. The injection is done with a 25-gauge needle, continuously moving the needle forward then backward while injecting, raising a contiguous ring around the base of the penis. When close to the dorsal vein of the penis, lift the needle over the vein subcutaneously while constantly advancing and injecting, making sure that no local anesthetic is deposited intravenously. The needle must be kept subcutaneous at all times.

Complications and Prevention

Bleeding and Hematomas. Bleeding and hematomas can be prevented by using a continuous mode of injection with small 25- or 27-gauge needles. When approaching the large dorsal vein of the penis, it is possible to skillfully lift the needle and course it subcutaneously above the vein while still injecting. This will avoid inadvertent IV injection of local anesthetic and bleeding or hematoma.

Local Anesthetic Toxicity. Even small amounts of local anesthetic, if directly injected intravenously, may cause toxicity. Additionally, if overly large volumes of local anesthetics are used for the block, they may get absorbed and cause delayed systemic toxicity. It is important to calculate and stay below the tissue toxic dose of the local anesthetic used. See "Local Anesthetic Systemic Toxicity," earlier.

Penile Ischemia and Necrosis. The arterial supply of the penis is through terminal branches of the pudendal artery, which gives rise to the bulbourethral arterial branches. The glans is supplied by the dorsal arteries, which give off circumflex branches perforating the tunica albuginea and supplying the distal end of corpora penis.

Penile ischemia/necrosis is a grave complication, usually caused by accidental use of vasoconstrictors (e.g.,

epinephrine).[92] All end organs with terminal vasculature are at risk of prolonged ischemia and necrosis (nose, fingers, toes, penis). Many cases of penile necrosis have been described in the pediatric literature; never use epinephrine in a penile block.

A possible temporary ischemia (presenting as pallor, pain, swelling, necrosis) has been successfully treated with vasodilation provided either by a regional block (caudal, spinal, epidural) or use of prostacyclin (PGI_2), the major prostanoid produced by the blood vessels. PGI_2 relaxes smooth vasculature, inhibits platelet aggregation, and can be administered intravenously or intraarterially.

Infection. Both methods of penile block must be done respecting full sterility precautions. In case of any infection, suspect skin flora.

Intraoperative Penile Erection

Intraoperative penile erection is a serious problem that may preclude Foley catheterization or cystoscope insertion and may increase bleeding and injuries to the corpora cavernosa and urethra during penile surgery. The mechanism for intraoperative penile erection is complex and poorly understood. It can be traced to a combination of neuroendocrine, vascular, and psychological factors acting upon the penile erectile organs.

Parasympathetic fibers (nervi erigentes) originating from S_2–S_4 sacral spinal segments innervate the penis. If parasympathetic tone predominates, the arteriolar dilation with subsequent erection of the corpora cavernosa causes erection. High sympathetic nervous tone causes arteriolar vasoconstriction with a subsequent reduction of the blood flow to the corpora cavernosa, causing penile detumescence. Vasoactive mediators also can affect the tumescence of the penis through a host of mediators like nitric oxide, bradykinin, or vasopressin.

The overall incidence of intraoperative penile erection is 2.5% for all male patients undergoing surgery, affecting those under general and epidural anesthesia evenly. The lowest incidence of 0.3% is encountered in spinal anesthesia.[93]

Clinically, intraoperative penile erection may occur from a multitude of factors. The most frequent are Foley catheterization (in 1% of general anesthesia cases) and penile manipulation (most frequently in patients <50 years of age).

A prolonged intraoperative erection is a urologic emergency.[94,95]

TREATMENT

Cooling the penis with ethyl chloride spray or anesthetizing with a penile block or pudendal block are frequently effective. Additionally, numerous pharmacologic methods have been used to obtain detumescence. Phenylephrine, a pure α-blocker, injected as 50–150 μg intracavernosally, provides detumescence within a few minutes. Vasodilators such as IV nitroprusside and inhaled amyl nitrate act through their relaxing effect upon the corpora cavernosa to produce detumescence. These might be contraindicated in hypotension, during regional blocks (sympathectomy), and in cases of increased intracranial or intraocular pressure. IV ketamine in doses of 0.5–1 mg/kg may be used. Ketamine's dissociative affect upon the limbic nervous system, coupled with its penile relaxing effect (decrease in central parasympathetic outflow), produces detumescence.[93]

Terbutaline 0.2–0.5 mg IV, a β_2-adrenergic agonist, has been used successfully to terminate erections. It causes a direct relaxing effect over the corpora cavernosa smooth muscles. Care must be taken in cardiac patients due to the tachycardia it may cause. Inhaled salbutamol, another β_2-adrenergic agonist, will work without cardiovascular symptoms. It will need a higher dose of 8–16 puffs (1600 μg).[96] Glycopyrrolate 0.2–0.3 mg IV, an anticholinergic with reduced chronotropic and CNS effects (better than scopolamine or atropine), works through its acetylcholine blocking effect in the nitric oxide penile erection mechanism.

Most sympathomimetics mentioned as useful penile detumescents in the urologic literature need to be evaluated seriously against their major cardiovascular complications. Epinephrine, norepinephrine, and metaraminol, to name a few, should be avoided if possible due to their intense β_1 activity.[93]

PREVENTION

Initial deepening of general anesthesia and avoiding early penile stimulation are important in preventing intraoperative penile erection. Pudendal block, penile block, or spinal anesthesia (instead of general) need to be considered more frequently for urologic procedures. In some elective cases, if prevention or milder treatment methods do not work, cancelling the case might be a better choice than causing inadvertent cardiovascular complications in a very sick ASA III–IV patient.[97]

Obturator Reflex

Obturator reflex is a problem potentially encountered during transurethral bladder tumor resections (TURBTs). Whenever the tumor resection gets close to the lateral wall of the bladder, the energy of the resectoscope can directly stimulate the obturator nerve through the bladder wall, which initiates a sudden violent pelvic thrust secondary to powerful contraction of the thigh adductor muscles. This may cause the resectoscope to inadvertently perforate the bladder. Obturator nerve block,[98,99] however risky[100] and difficult to perform, seems to be useful in preventing obturator reflex in conjunction with general or regional anesthesia. It was hoped that the use of the newest technologies, such as the new bipolar thermocoagulation devices,[101,102] would diminish the incidence of obturator reflex.

However, the obturator reflex can be totally prevented only if the patient is under general anesthesia and fully muscle relaxed. General anesthesia can be selected at the beginning of the case or initiated at any point later during the case if the tumors to be resected seem to be positioned on the unfavorable lateral wall of the bladder. Awareness of the problem and good communication between the urologist and anesthesiologist are essential to prevent the occurrence of obturator reflex.

Postoperative Pain Management

Most urologic procedures produce significant postoperative pain. Postoperative pain management should be discussed and planned jointly by the urologist and anesthesiologist before the surgery. The choice of anesthesia is crucial in partially or totally preventing postoperative pain. Patients waking up after general anesthesia have full pain, whereas patients after regional anesthesia have somewhat less pain.

The use of heavy pain medication postoperatively may produce its own undesirable symptomatology, such as PONV, unpleasant sedation, confusion (prolonged in the very old), residual pain, and longer recovery times. Ideally, the best anesthesia technique will simultaneously provide adequate stress-free anesthesia for the urologic procedure and prolonged postoperative pain relief in the PACU. This is best accomplished through the judicious use of nerve blocks and meperidine spinal anesthesia in association with propofol TIVA. See "Further Prevention of Regional Anesthesia Complications," earlier.

Various pain management techniques can be employed postoperatively.

NARCOTICS

Major narcotics still are relied upon heavily for immediate postoperative pain management. Morphine has been successfully used in single injectable doses on demand. It produces only moderate pain relief, with deep sedation, confusion, PONV, and histamine release. Morphine is very useful in narcotic sensitized patients, alone or in association with other methods of analgesia. See "Intravenous Patient-controlled Analgesia" later.

We find that fentanyl 100–150 μg (depending on patient's weight), used IM rather than IV (using the patient's large quadriceps muscle as a drug depot) along with 10 mg lidocaine added to alleviate injection discomfort, is a more potent analgesic than morphine and causes less deleterious side effects: Fentanyl used in this fashion causes no significant immediate respiratory depression, less PONV, and no histamine release (tachycardia, hypotension, itchiness) and provides very good pain relief for several hours. Fentanyl proves even more useful in patients with relative or absolute contraindications to other pain medications such as morphine, meperidine, hydromorphone (Dilaudid), or NSAIDs.

NONSTEROIDAL ANTIINFLAMMATORY DRUGS

NSAIDs are very useful after shorter, less painful procedures, alone or in conjunction with minor narcotics, or in the context of multimodal analgesia. Most patients tolerate NSAIDs well for short treatment courses. Patients with known asthma history, allergy to NSAIDs, renal failure, GI problems (e.g., gastritis, ulcer), or coagulopathies should not be given NSAIDs. Acetaminophen (Tylenol) is a viable substitute, alone or in conjunction with narcotics.

Ketorolac tromethamine (Toradol) is safe in a single IM dose of 60 mg and provides excellent 6- to 8-hour analgesia without any sedation. IV Toradol has a short effect, and thus is never useful for significant postoperative pain relief (as per label warning). Toradol also may be used in combination with other medications. We prefer a novel combination injection of Toradol 60 mg IM, combined with a separate dose of 75–100 μg fentanyl IM, for a long-acting postoperative analgesia without significant respiratory depressant effect.

TRAMADOL

Tramadol (Ultram), a centrally acting moderate analgesic, is used in doses of 50 mg or 100 mg PO every 4–8 hours, and is safe for patients <75 years old. Tramadol decreases the seizing threshold of patients with seizure disorder and interacts negatively with a host of psychotomimetic drugs (serotoninergic syndrome).[103]

MULTIMODAL ANALGESIA

Different regimens mixing NSAIDs with minor or major narcotics and local anesthetics/nerve blocks prove to be very efficient, facilitating a rapid recovery.[104,105] Multimodal analgesia is heavily relied upon in ambulatory surgery.

INTRAVENOUS PATIENT-CONTROLLED ANALGESIA

The decision of what intravenous patient-controlled analgesia (IV-PCA) to use should be based on the type of procedure, expected intensity of postoperative pain, and type of patient (narcotic-naïve versus narcotic-sensitized).

We have found that patients frequently become narcotic-sensitized after only a few days of receiving μ-receptor stimulators (e.g., Percocet, Vicodin, morphine, hydromorphone) at any time during the past 6–12 months. Those patients will require a μ-receptor stimulator IV-PCA (morphine or hydromorphone) and will not respond well to fentanyl IV-PCA (which is mainly a κ-receptor stimulator).

Morphine IV-PCA is frequently used for in-patients. Many physicians tend to underdose morphine IV-PCA. We prefer fentanyl IV-PCA in all cases, except for the narcotic-sensitized (μ-receptor) patient.

Fentanyl IV-PCA provides superior analgesia, with less respiratory depressant effect (shallow breathing, respiratory rate <6/min, CO_2 retention), less CNS depressant effect (somnolence, disorientation), less histamine release (tachycardia, hypotension, itchiness), and less PONV than morphine. PCA doses should be down-adjusted for smaller patients and less painful surgeries (e.g., laparoscopies, robotics).

IV-PCAs are mainly maintenance regimens. For them to be successful, the patient must already be comfortable (painless) before leaving the OR and arriving in the PACU. Sometimes several narcotic boluses have to be administered to render the patient comfortable before starting the IV-PCA in the PACU.

EPIDURAL PATIENT-CONTROLLED ANALGESIA

Compared to any IV-PCA, epidural PCA has the advantage of better analgesia achieved with diminished sedative effect and even less frequent PONV. Epidural PCA uses various combinations of low concentration local anesthetic mixed with a potent narcotic (fentanyl, sufentanil).

THE OBSTRUCTIVE SLEEP APNEA PATIENT

For safe treatment of the clinically documented obstructive sleep apnea patient, use a nonnarcotic-based epidural PCA (e.g., bupivacaine 0.1% or 0.125%).

Laparoscopy and Robotic-assisted Laparoscopy

Robotic surgery in urology is a natural evolution of laparoscopic GU surgery. A large number of urologic procedures were developed robotically, along with continually evolving robotic platforms and methods. Various new intraoperative imaging techniques have been integrated into the robotic platform, including ultrasound (US) and near infrared fluorescence imaging (NIRF).

Anesthesia knowledge, experience, and versatility have directly paralleled this surgical evolution not only in achieving great patient outcomes but also in diagnosing, treating, and preventing the anesthesia-related complications associated with robotic urologic surgery.

The physiology and pathophysiology of laparoscopic and robotic surgery in urology are virtually identical. Therefore, we treat them together in this section.

Pathophysiology of pneumoperitoneum is different in patients under general anesthesia versus patients who are awake or sedated under regional anesthesia.

PATHOPHYSIOLOGY OF PNEUMOPERITONEUM (CO_2 INSUFFLATION)

Pneumoperitoneum Under General Anesthesia

Several processes constantly interplay during CO_2 insufflation: mechanical effects, neurohormonal effects, cardiovascular effects, temperature effects, respiratory effects (mechanical and CO_2 absorption), and circulatory effects.

Mechanical Effects of CO_2 Insufflation. Normal supine intraabdominal pressure (IAP) is 5–7 mm Hg, with a higher baseline level for morbidly obese patients (9–14 mm Hg). Increasing IAP with CO_2 insufflation significantly reduces the functional residual capacity of the lungs. Also, it causes a transient increase in venous return followed by a drop in cardiac preload ultimately resulting in a drop in cardiac output (CO) of up to 48%.[106] These effects may diminish at lower insufflation pressures. Remarkably, in an animal model, insufflation at a pressure of 12 mm Hg exerted a minimal effect on hemodynamic function.[107] This has useful potential implications for the laparoscopic/robotic surgeon.

Neurohormonal Effects. Increase in IAP and subsequent hypercapnia cause a release of catecholamines and vasopressin. The renin-angiotensin-aldosterone axis becomes activated. A parallel time course profile between these changes and changes in BP, systemic vascular resistance (SVR), and cardiac index (CI) suggests a cause–effect relationship.[108]

Cardiovascular Effects. Cardiovascular performance during pneumoperitoneum is affected by the interaction of several factors including neurohormonal release,[108] intravascular volume,[109] cardiorespiratory status,[110] and positioning.[111]

In patients with mild heart disease or in ASA III and ASA IV patients with severe systemic disease, the direction of changes in CI, SVR, and mean arterial BP is the same as in healthy patients, except that the initial decrease in CI and increase in SVR are more pronounced. Also, there is a significant increase in oxygen demand as expressed by great increases in left ventricular stroke work index.[111–114] CO_2 insufflation done in the supine position (versus Trendelenburg) produces a lesser initial decline in CI (of significant clinical implication). All these changes revert to normal upon release of the CO_2 (deflation).

Temperature Effects. Body core temperature drops significantly during surgery with continuous CO_2 insufflation.[110] This change is more pronounced in older patients and tends to continue despite warming throughout the procedure.

Respiratory Effects: Mechanical. Changes in pulmonary function during CO_2 insufflation include reduction in lung volumes, decrease in pulmonary compliance, increase in peak airway pressures, and reduction in FRC.[115–117] Insufflation of CO_2 at 15 mm Hg lowers an already decreased FRC (due to induction of general anesthesia and positioning), exacerbating the ventilation/perfusion (V/Q) mismatch.[118] Positive pressure ventilation will recover some of the FRC, reducing the potential for hypoxia.[119,178] The greatest reduction in FRC is seen in obese patients, thus creating a significant V/Q mismatch during pneumoperitoneum.[120] The existence of intrapulmonary shunting in COPD patients places them at extra risk of hypoxia during laparoscopic surgery.

Respiratory Effects: Carbon Dioxide Absorption. Interestingly, CO_2 absorption is greater during extraperitoneal procedures than during intraperitoneal procedures.[121,122] Elimination of CO_2 is biphasic. Early rapid elimination occurs at the beginning of insufflation and is followed by a slower elimination later on. This biphasic mode is maintained at lower as well as at higher inflating pressures.[121] Intentional hypercarbia increases plasma catecholamines and cardiac output and it decreases SVR directly through the vasodilating effect of CO_2 and indirectly by stimulating the sympathetic nervous system. Nitrous oxide (N_2O) administered during CO_2 insufflation tends to exaggerate the cardiovascular depressive effects of CO_2. Elimination of CO_2 is not problematic in healthy patients. For sicker ASA III or ASA IV patients, minute ventilation requirements and peak airway pressures are higher in order to assure normocarbia during laparoscopy.[123] Furthermore, in some sicker patients, end tidal CO_2 may not be a true reflection of their arterial partial pressure ($PaCO_2$). In these patients, refractory hypercapnia might occur during laparoscopy. Preoperatively, a pulmonary function test (PFT) showing diffusion defects <80% of predicted and FEV1 <70% of predicted identifies patients at risk.[124]

Specific Circulatory Changes. Regional blood flow changes during laparoscopy have been carefully studied. These circulatory effects alter organ perfusion in specific

ways and pose problems when operating on ASA III and ASA IV patients.

CEREBRAL BLOOD FLOW. Cerebral blood flow and intracranial pressure (ICP) increase significantly during CO_2 insufflation regardless of the level of $PaCO_2$.[125] There is a linear increase in ICP with increasing IAP. Trendelenburg position further increases ICP to 150% of initial.[126]

SPLANCHNIC BLOOD FLOW. Changes in splanchnic blood flow are mediated through a direct increase in IAP and through mesenteric vasculature compression.[127] Normal IAP is 4–5 mm Hg. The effect of low IAP (7 mm Hg) on splanchnic perfusion is negligible. Higher IAP (14 mm Hg) decreases portal and hepatic blood flow and decreases intestinal mucosal pH.[128] Increased IAP through CO_2 insufflation stimulates the release of antidiuretic hormone (ADH) with subsequent vasoconstriction of the splanchnic bed. Splanchnic ischemia is a serious risk factor for sepsis and multi-organ system failure, which can outlast CO_2 deflation by as much as 18 hours.[129]

HEPATIC BLOOD FLOW. Hepatoportal blood flow varies in direct proportion to changes in IAP. At low IAP (7 mm Hg) the portal blood flow is reduced 37%. At higher IAP (14 mm Hg) portal blood flow is reduced 53%.[130] The reverse Trendelenburg position significantly reduces the hepatoportal flow.[131]

RENAL BLOOD FLOW. CO_2 insufflation reduces flow in the renal cortex and medulla. There is a transient reduction in GFR, creatinine clearance, and urinary output.[132,133] Urine output and creatinine clearance tend to decrease at higher IAP (14–15 mm Hg). Any method that diminishes IAP such as low inflating pressures, retraction,[134] or abdominal wall lifting[135] promotes stable renal dynamics during laparoscopy. Humoral factors such as renin[136] and ADH are released by increased IAP and cause vasoconstriction with decreased urine output and urea excretion (GFR unchanged).[137]

Pneumoperitoneum Under Regional Anesthesia

Respiratory Changes. The previously described respiratory changes in patients under general anesthesia are less evident in patients under regional anesthesia. On insufflation, expired volume per unit time increases significantly, with respiratory rate increasing about 50% from baseline. During pneumoperitoneum under regional anesthesia, venous CO_2 remains unchanged along with $PaCO_2$.[138] Under epidural anesthesia, respiratory mechanisms remain intact, so patients can adjust their minute ventilation during CO_2 insufflation in order to normalize their $ETCO_2$. These results suggest that epidural anesthesia may be a safer alternative to general anesthesia because it is not associated with significant ventilatory depression.

Cardiovascular Changes. Hemodynamic changes during regional anesthesia are different from general anesthesia. The Trendelenburg position and CO_2 insufflation have little effect on heart rate and mean arterial pressure.[138] However, they affect the sensory level of the hyperbaric spinal anesthesia, which ends up significantly higher than expected thus magnifying the normal cardiovascular impact of the spinal block. To counteract this, smaller doses (minidoses) of local anesthetic in combination with potentiating narcotic minidoses are recommended.[139] Additionally, simultaneous use of the IV/IM ephedrine regimen will provide stable cardiovascular parameters throughout the case. See "Combined Intravenous and Intramuscular Ephedrine for Cardiovascular Stability," earlier.

OPERATIVE MANAGEMENT

Patient Monitoring

During laparoscopy/robotics, general monitoring (e.g., electrocardiogram, SaO_2, $ETCO_2$, BP, and temperature) is appropriate for healthy and slightly obese patients.[140] There might be larger fluctuations in $ETCO_2$ and $PaCO_2$ in patients with serious pulmonary disease or the morbidly obese; therefore, an arterial line is advisable for serial blood sampling, SaO_2 determinations, and tighter BP monitoring. Unchecked increases in CO_2 might cause arousal in patients under general anesthesia because of the intense catecholamine release secondary to hypercarbia. Using a BIS monitor helps with anesthesia depth assessment.[141]

General Anesthesia

The great majority of laparoscopies and robotically assisted laparoscopies in urology, both diagnostic and therapeutic, are done under general anesthesia in the United States. Propofol TIVA is also a good choice, with specific benefits for patients with a past history of PONV. See "Propofol Total Intravenous Anesthesia (Propofol TIVA)," earlier.

Choice of Airway. Endotracheal intubation is used for most patients. This ensures an airway protected against gastroesophageal reflux and enables the anesthesiologist to effectively control $ETCO_2$. During pneumoperitoneum, satisfactory $ETCO_2$ (34–35 mm Hg) is obtained by only a 15–25% increase in minute ventilation. In patients with COPD, it is safer to increase the respiratory rate rather than the tidal volume because of the risk of tension pneumothorax caused by potential rupture of alveolar bullae.[142,143]

LMA also has been used extensively in laparoscopic surgeries.[144] The fear of inadvertent gastroesophageal reflux has not been substantiated in studies done with clinical monitoring[144] and continuous esophageal pH monitoring.[145] General anesthesia can be safely performed using a correctly placed LMA.

When the patient is breathing spontaneously through an LMA or a mask, if inappropriately high levels of $ETCO_2$ are reached or are difficult to prevent (as in patients who are morbidly obese or who have severe pulmonary disease), the surgery should be stopped, the abdomen deflated, and the patient intubated for the conclusion of the surgery. High ASA status (III or IV) coupled with preoperative low vital capacity volumes and low forced expiratory volumes are good predictors of intraoperative hypercapnia and acidosis in laparoscopic procedures.[124]

Nitrous Oxide. N_2O is the second most diffusible gas in the body after CO_2. In conjunction with insufflated CO_2, N_2O readily overdistends most closed cavities such as the bowel, colon, inner ear, and bladder and increases the resident gas volumes by 100–200%. N_2O exaggerates the

deleterious cardiovascular effects of CO_2. It also is associated with increased rates (30%) of PONV. Because of these negative characteristics, N_2O should never be used during laparoscopic/robotic surgery.

Regional Anesthesia

Regional anesthesia (spinal, epidural, or combined spinal/epidural) can be used in laparoscopic/robotic surgery as an alternative anesthesia choice in patients with severe cardiopulmonary disorders that contraindicate general anesthesia. Other advantages of regional anesthesia include decreased or lack of postoperative pain, decreased PONV, more rapid recovery with shorter PACU stay, fewer hemodynamic changes,[143] fewer respiratory changes,[146] and the availability of an epidural catheter for extended postoperative analgesia.[147] A disadvantage of regional anesthesia for laparoscopy is that it often requires the surgeon to work with a lower insufflation pressure (9–12 mm Hg). Additional disadvantages include the requirement of a cooperative patient and gentler surgical technique. Oversedation can cause hypoxia.[148]

Epidural Anesthesia. Epidural anesthesia is considered safe and practical in short procedures and in outpatient laparoscopic surgery. It does not significantly inhibit respiratory function, thus patients can increase their minute ventilation easily to compensate for the increase in $PaCO_2$, assuring that $ETCO_2$ remains unchanged.[138] The epidural technique has been used successfully for patients with advanced COPD.[138,146,147] Epidural anesthesia also has been used successfully in gasless laparoscopic procedures, providing cardiovascular and respiratory safety similar to general anesthesia.[149]

Spinal Anesthesia. In this age of short outpatient laparoscopic surgery, spinal anesthesia may be used to provide fast onset, deep, reliable blocks with easily controllable length of action. The classic hyperbaric spinal technique should be replaced by minidose spinals because of the propensity for cephalad spread of the sensory level during increased IAP and in the Trendelenburg position.[139,150] Ideally, minidoses of local anesthetic, potentiated by the addition of minidoses of narcotics, are used.[151] Even more effectively, minidoses of meperidine (30–40 mg) also provide long-lasting postoperative pain relief. See "Meperidine Spinal Anesthesia," earlier.

Local Anesthesia. However controversial, local anesthesia is used for ultra-short diagnostic laparoscopies and is adequate for special microlaparoscopic procedures done in nonobese patients.[143,152–157] In all these cases, preemptive port site local anesthetic infiltration greatly diminishes postoperative pain.

Peripheral Nerve Blocks. Several nerve block techniques have been described in conjunction with laparoscopic surgery, including rectus sheath block,[158] inguinal block,[158] and paravertebral block.[159] These blocks prove to be useful adjuncts to general anesthesia or TIVA, and they provide effective postoperative pain relief in various types of laparoscopic surgery. They result in reduced PONV and increased patient satisfaction.

COMPLICATIONS OF PATIENT POSITIONING IN ROBOTIC SURGERY

Positioning the patient for various robotic urologic procedures is very specific. See also "Positioning-related Complications," earlier. Some cases require a supine position (radical prostatectomy, sacrocolpopexy); others require a semi-lateral position (radical nephrectomy, partial nephrectomy, adrenalectomy, nephroureterectomy) or flank position (partial and/or radical nephrectomy-posterior retroperitoneal approach).

In most cases the legs are symmetrically placed in stirrups. In some cases, they are purposely placed asymmetrically. Most cases will be positioned in a steep (30–45 degrees) Trendelenburg position, though a moderate 20–30 degrees is sufficient to maintain the advantages of the position (e.g., moving bowels away from pelvis) while minimizing the negative effects of steep Trendelenburg.

Various complications have been described as a result of positioning, including nerve injuries, compartment syndrome, rhabdomyolysis, dermal injuries, and eye injuries. Understanding the mechanism and etiology of these complications is vital for effective prevention and treatment.

Two general pathophysiologic mechanisms are responsible for position-related complications in robotic urology: neural mechanisms and vascular mechanisms.

Neural Mechanisms

Neural mechanisms clinically present as peripheral neuropathies and intraocular neuropathy (ION). These neuropathies can be mild or severe. Nerves can be stretched or compressed or can get ischemic. Depending on the degree of insult, the result is a neuropathy that can have a short (neuropraxis = weeks) or long (months) duration, or sometimes may become permanent. Once degenerated, a damaged nerve's regrowth rate is about 1 mm/day.[160]

Peripheral Neuropathy of Lower Extremity. Superficial peroneal nerve injury is frequently encountered, occurring mostly in the high lithotomy position, especially in surgeries lasting over 6 hours. This type of neural complication is nearly eliminated by repositioning to the supine position.[161]

Peripheral Neuropathy of Upper Extremity. Nerve trauma can occur secondary to sliding in steep Trendelenburg position, during the use of shoulder braces, or due to compression from low-positioned robotic arms. Ulnar nerve lesions can occur frequently in these cases. Awareness, correct positioning, additional padding, and the use of lateral bed extenders (as padded arm rests) nearly eliminates ulnar nerve injuries and other upper extremity injuries. In the lateral or semi-lateral position, careful padding and positioning of the upper arm minimizes the risk of upper arm neural damage. Brachial plexus injury occurs when arms are hyperextended with or without contralateral tilt of the head. "Axillary" roll (high thoracic roll) should be used to elevate the upper thorax from the OR table and thus prevent brachial plexopathy.

Aggravating factors for these neuropathies include increased BMI, a high lithotomy position, shoulder braces, inadequate padding, and lack of axillary roll.

Intraocular Neuropathy. Etiology of intraocular neuropathy (ION) may be multifactorial: local edema due to the Trendelenburg position, orbital stretching, direct compression of the eye in the prone position, the increase in end expiratory CO_2 that may increase intraocular pressure (IOP) directly and/or through choroidal vasodilation, and increased secretion of aqueous humor.[162] To prevent ION, minimize the degree of Trendelenburg position, avoid direct compression of the eye, and maintain normocarbia.

Vascular Mechanisms

Ischemic compression of any extremity may cause compartment syndrome and/or rhabdomyolysis. The Trendelenburg position causes a significant decrease in deep calf muscle mixed tissue oxygen saturation (hypoxia) during urogenital robotic surgery.[163] Additionally, a steep (30–45 degrees) Trendelenburg position while in the lithotomy position may cause patient slide cephalad with resulting pressure on the calves and legs (ischemia). Prevention involves the use of special nonslip pads. A lesser Trendelenburg (16 degrees) position will preserve the surgical advantages while minimizing the risks associated with Trendelenburg position (increased intra-abdominal, intrathoracic, intracranial, and intraocular pressure).

Compartment Syndrome. Compartment syndrome (CS) is a condition that results from prolonged impairment of limb perfusion secondary to compression, edema, and ischemia of a body compartment. CS may lead to internal cellular swelling and to further self-sustaining ischemia, followed by potential vascular and nerve damage, along with massive muscle destruction leading to rhabdomyolysis. A wide range of complications can arise from CS, including temporary to permanent nerve damage, muscle necrosis, sepsis, rhabdomyolysis, amputation, and death.

Risk factors for CS are patient related (morbid obesity, peripheral vascular disease [PVD], hypovolemia/dehydration, hypotension, hypothermia, drug-induced prolonged peripheral vasoconstriction) and/or procedure related (high lithotomy position, Trendelenburg position, compression of extremity circulation, dependent limb).[164] CS can be diagnosed using the six "P"s: progressive pain, paresthesia over peripheral nerve distribution, pain upon passive stretch of the involved muscle, pink skin, pulse, and compartment pressure (CP) over 30 mm Hg in any compartment.[165]

The presence of pedal pulse or pulse oximetry is not adequate for excluding the CS diagnosis, though in advanced CS cases pulse would be absent. Myoglobin in the urine heralds impending CS; however, the amount of myoglobin does not directly correlate with the degree of tissue destruction. The best method to ascertain the gravity of the CS syndrome is to directly measure CP, which can be done invasively or noninvasively, using a more modern fiberoptic device employing near infrared spectroscopy (NIRS) for continuous display of CP.

PREVENTION OF COMPARTMENT SYNDROME. Preoperatively, advise patients to lose weight and prehydrate to euvolemia.

Intraoperatively use the correct positioning (lower the lithotomy position, use 16 degrees Trendelenburg, no pressures, no constrictions). Avoid prolonged surgery over 5 hours, and in longer surgeries (over 6–7 hours) try to reposition the patient midway during the procedure. Use transparent drapes to observe limbs for changes in color and size. Maintain adequate blood pressure and adequate perfusion pressure, and avoid vasoconstrictor drugs; use mannitol if necessary as a free radical scavenger. In very high–risk patients (ASA IV, heavy smokers, super-obese, PVD, etc.) use prophylactic intraoperative CP monitoring. If regional anesthesia is being used, be sure to maintain normal mean arterial pressure (MAP).

Postoperatively, it is important to keep a high awareness, since CS may appear some time after the injury as a result of tissue reperfusion. Use close monitoring.

TREATMENT OF COMPARTMENT SYNDROME. Treatment should start early. Pressures of 50 mm Hg or over for 4–8 hours will likely produce irreversible muscle changes. Fasciotomy is generally recommended somewhere around pressures of 30–45 mm Hg and it is recommended not to wait too long. Current belief is that a CP within 20 mm Hg below the diastolic BP of the patient will likely prevent unnecessary fasciotomies and irreversible neuromuscular damage.[166]

Identify and discontinue ischemia (e.g., transparent drapes, repositioning), decompress all compartments involved (fasciotomy), and properly rehydrate the patient (he or she may lose significant plasma volume by oozing post-fasciotomy). When intense CS leads to rhabdomyolysis, medical treatment must begin early in order to be successful. Diuresis must be forced with mannitol and is considered important in treating renal failure secondary to rhabdomyolysis. In very advanced cases of CS, a delay of 8–10 hours should trigger a reassessment of the need for fasciotomy.

Rhabdomyolysis. Rhabdomyolysis is a complication of muscle trauma–related crush injuries. It also may occur secondary to muscle ischemia due to prolonged muscle compression.[167] Rhabdomyolysis is frequently associated with CS.[168,169] In advanced CS, increased tissue pressures (due to edema and secondary regional ischemia) lead to muscle necrosis and release of toxic catabolytes and large quantities of acidic myoglobin. High levels of CPK (a marker) are released as well in the general circulation, which somewhat parallels the clinical course of the rhabdomyolysis. Acute renal failure (ARF) is a common complication. There are numerous case reports of rhabdomyolysis after laparoscopic/robotic cases of donor nephrectomy, partial nephrectomy, radical nephrectomy,[170–172] and long bariatric surgeries in morbidly obese patients.[173,174]

PATHOPHYSIOLOGY OF RHABDOMYOLYSIS. The pathophysiology is multifactorial. Rhabdomyolysis is the result of an ischemic injury to the nephrons secondary to intravascular volume depletion, coupled with renal vasoconstriction and intraluminal cast formation. Ischemic muscle edema reduces intravascular blood volume, creating pre-renal conditions for acute renal failure as well. Furthermore, heme proteins will reduce the nitric acid reserves of the kidney with a secondary vasoconstrictive effect, which further reduces the glomerular filtration rate (GFR).

Complications of rhabdomyolysis include metabolic acidosis, disseminated intravascular coagulation (DIC), respiratory failure, and shock. Electrolyte abnormalities include

hypocalcemia, hyperkalemia, and hyperphosphotemia. These electrolyte changes may occasionally cause severe cardiac arrhythmias.

TREATMENT OF RHABDOMYOLYSIS. Most treatment guidelines are based on the animal model of ARF secondary to rhabdomyolysis.[175,176] They recommend vigorous hydration, alkalinization with sodium bicarbonate, and diuresis (mannitol, loop diuretics, and "renal" dopamine). Alkalinization greatly increases the solubility (and elimination) of myoglobin (2% solubility at pH 5 increases to 80% at pH of 8).[175] In advanced cases (shock), invasive monitoring, dialysis, and other supportive therapies are needed.

Patients may present to the PACU with bruising, excessive muscle (compartment) pain, local swelling, dark brown urine, and oliguria. Serum levels of creatinine, CPK, and myoglobin should be measured. If there is compartment swelling, an immediate vascular consult with tissue pressure monitoring should be obtained. A more precise noninvasive technology using near infrared technology to quantify tissue ischemia by measuring dioxyhemoglobin levels has been developed.[177]

PREVENTION OF RHABDOMYOLYSIS. Very muscular and/or high BMI patients are at highest risk for rhabdomyolysis. Use proper heavy cushioning of the OR table, shorten procedures, and in long cases call for time out and reposition the patient. Do not use kidney rest.

CLINICAL COMPLICATIONS DURING PNEUMOPERITONEUM

Normal intraabdominal pressure (IAP) is 5–7 mm Hg. During pneumoperitoneum, the inflating pressures get transmitted from the abdomen to the chest, head, neck, and eyes. These pressures tend to be exaggerated by the steep Trendelenburg position.

Pneumopericardium, Pneumomediastinum

Complex cases of pneumothorax associated with pneumopericardium, pneumomediastinum, and periocular emphysema have been described. High inflating pressures probably contribute to the occurrence of these complications.[178–180] Signs of cardiac tamponade may occur, including arrhythmias, muffled heart sounds, jugular vein distention (JVD), drop in BP and cardiac output, and superior vena cava syndrome. Superior vena cava syndrome manifests as a "blue cape" cyanosis and swelling of the head and neck (due to the impingement upon the venous return to the right heart). Decreasing the inflating pressures to <15 mm Hg or completely releasing the CO_2 from the abdominal cavity is sufficient to halt and reverse these complications.[181]

Pneumothorax

Pneumothorax may occur upon insufflation in congenital defect of the diaphragm. Iatrogenic pneumothorax may occur during inadvertent percutaneous or transdiaphragmatic puncture of the lung (e.g., during posterior retroperitoneal approach in nephrectomy and partial nephrectomy). Existing pulmonary blebs (or bullae) may rupture during mechanical ventilation. A bleb is a small (less than 1 cm) air collection located within the visceral pleura. It can rupture spontaneously or through mechanical ventilation. Sometimes patients present with multiple blebs. Bulla is a larger (greater than 1 cm) air space formed in the lung parenchyma. A giant bulla (larger than 30% of the hemithorax) is at great risk of rupturing. A Sudden hypoxia (drop in SaO_2), increase in airway pressure, and/or cardiac arrhythmias should alert to the possibility of pneumothorax. Prevention, once blebs or bullae are noticed, involves the use of small tidal volumes coupled with higher respiratory frequency on mechanical ventilation. Treatment comprises correct side diagnosis and chest tube placement, which assures lung re-expansion.

Tension Pneumothorax

Pneumothorax leading to tension pneumothorax, a rare but potentially life-threatening complication, has been described in both intraperitoneal[182] and extraperitoneal[183] laparoscopy. CO_2 can enter the thoracic cavity through the natural esophageal or aortic hiatus, or it might dissect through a congenitally open pleuroperitoneal hiatus.[184,185] A sudden large accumulation of CO_2 in the pleural cavity or an accidental rupture of lung bullae may cause tension pneumothorax.

The ipsilateral lung gets collapsed, and there is a contralateral mediastinal shift. The lung's respiratory surface is quickly diminished leading to hypoxia. This is a life-threatening emergency. There is a gradual compression of the vena cava with a diminishing of venous return to the heart and a sudden decrease of cardiac output (CO). There is a noticeable contralateral shift of the trachea as well as cyanosis, increased engorgement of the neck veins (JVD), sudden increase in ventilatory airway pressure, and hypoxia. The patient's condition deteriorates quickly. An emergency chest x-ray is diagnostic.

Treatment should be immediate. In emergencies, when cardiovascular collapse is imminent, the best method is to stop surgery and immediately deflate the abdomen. Careful manual ventilation soon promotes CO_2 reabsorption, re-expands the affected lung, and restores normal cardiovascular function. In extreme cases, an emergency thoracocentesis (most frequently done over the second intercostal space at the mid-clavicular level using a 3.5-inch 14-gauge – or larger – needle) releases the CO_2, allowing manual re-expansion of the lung. Maintaining inflating pressures at <15 mm Hg might prevent such occurrences.

Subcutaneous Emphysema

Following CO_2 insufflation, an inadvertent subcutaneous emphysema might occur, with a reported incidence of 0.4–2%.[186,187] It may be limited to the abdominal wall, or it may dissect all the way around the chest wall, neck, head, and thighs, creating a lot of easily palpable subcutaneous crepitus. On some extreme occasions, increased $ETCO_2$ and respiratory acidosis have been described.[188] Careful deep insertion of the Veress needle, maintaining the inflating pressures at <15 mm Hg, and visualization of the intraperitoneal position prevent this complication.[189]

Subcutaneous emphysema is usually benign and resolves spontaneously. CO_2 with its known high diffusability is not dangerous subcutaneously and will be spontaneously eliminated through reabsorption (and lungs) within a few hours. In advanced cases, $ETCO_2$ should be monitored in the PACU and patients placed on O_2 by mask to avoid hypoxia through rebreathing.

Cardiac Arrhythmia

Bradycardia sometimes occurs during the intraperitoneal CO_2 insufflation. It is thought to be due to a vagally mediated action due to peritoneal distention. Prevention involves being mindful and attentive. Treatment comprises an anticholinergic administered simultaneously with abdominal deflation. When normal heart rate reappears, re-insufflation and the procedure may continue.

Carbon Dioxide Gas Embolism

CO_2 embolism (CO_2 entry into the vascular bed) can occur following accidental puncture of veins or a very vascular organ (e.g., liver). CO_2 gas embolism during laparoscopic surgery can be nonfatal[190] or fatal.[191] Hypoxia, arrhythmias, cyanosis, precordial "mill wheel" murmur, and sudden drop in $ETCO_2$ and $PaCO_2$ (due to the reduction in pulmonary venous return) may be followed by cardiovascular collapse. Gas embolism may occur at any time during CO_2 insufflation. In the presence of a patent right to left communication (e.g., patent atrial septal defect, patent foramen ovale), coronary and cerebral CO_2 embolism may result.[192]

Subclinical forms of CO_2 embolism occur somewhat frequently and may be detected using transesophageal echocardiography (TEE).[193]

Careful surgery done by an experienced surgeon, a high suspicion index by the anesthesiologist, the use of a precordial stethoscope, a large bore central line, and TEE used in high-risk patients with advanced multisystem disease help in early detection and treatment of gas embolism. Insufflation should be done in supine position since Trendelenburg position is known to decrease venous pressures. Air entry and air embolism are considered much more serious than CO_2 embolism, because CO_2 has a much higher diffusing capacity and can be eliminated faster. Thus, the air from the insufflating tube should be replaced with CO_2.

Once CO_2 embolism is diagnosed, immediately stop insufflation, deflate the abdomen, and flood the operative area with fluid (NS, Ringers lactate). The patient should be rolled onto his or her left side to facilitate CO_2 elimination from the heart. A CVP line may be inserted, and/or in desperate cases direct cardiac puncture may be needed to aspirate the CO_2.[194]

Shoulder Pain

Although the mechanism of postoperative shoulder pain is unclear, it is theorized that CO_2 entrapment under the diaphragm produces phrenic nerve irritation and referred pain to C4 (shoulder). Many surgical maneuvers have been described as potential treatment, including low pressure pneumoperitoneum.[195] The use of an abdominal wall lifter (AWL) is no longer recommended.[195] Various postoperative medications (e.g., NSAIDS, narcotics, pregabalin) were found to have limited usefulness.[196]

The most successful methods involve eliminating intra-abdominal CO_2 either by filling the abdomen with saline solution at the end of surgery[197] or using the Valsalva maneuver in Trendelenburg position at the the end of surgery.[198,199] At our institution, we routinely use the Valsalva maneuver at the end of all laparoscopic/robotic surgeries with excellent results.

References

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Chapter 6 Questions

1. What are the most common risks for anesthetic morbidity and mortality?
   a. Age >50
   b. Chronic renal failure, multiple genitourinary (GU) surgeries
   c. Preexisting cardiac and pulmonary conditions
   d. Smoking, chronic obstructive pulmonary disease (COPD)
   e. Previously encountered difficult airway

2. Which of the following statements is true for morbid obesity and obstructive sleep apnea?
   a. Morbid obesity is defined as BMI of 35–39.9 kg/m^2
   b. A morbidly obese patient with multiple comorbidities presents a reasonable risk for ambulatory surgery
   c. Obstructive sleep apnea is rarely associated with morbid obesity
   d. Continuous positive airway pressure (CPAP) and/or bilevel positive airway pressure (BiPAP) should be discontinued 2 days before surgery
   e. Ambulatory surgery is safely done on morbidly obese patients without comorbidities

3. When doing preoperative anesthesia risk stratification, an ASA III patient is:
   a. A patient with one well-controlled systemic disease
   b. A patient with childhood history of asthma, gastroesophageal reflux disease (GERD), and history of smoking
   c. A patient with obstructive sleep apnea and mitral valve prolapse
   d. A patient with ejection fraction = 30%, poorly controlled diabetes mellitus, and coronary artery disease with two drug-eluting stents (12 months ago)
   e. A patient with systemic lupus erythematosus (SLE), 3 months postradical cystectomy

4. Which of the following statements are true about patients with hyperreactive airway?
   a. Preoperative history taking is very important in identifying patients with a hyperreactive airway
   b. Adequate depth of anesthesia should be achieved before operating or manipulating the airway of these patients
   c. Patients with bronchial asthma (or with a history of it), obesity, or COPD, smokers, patients with eczema, or those with recent upper respiratory infections (within 4–6 weeks) frequently present with a hyperreactive airway
   d. All of the above
   e. b and c

5. Which of the following statements are true about patients with malignant hyperthermia (MH)?
   a. All inhalational anesthetics and succinylcholine can trigger MH
   b. There is a nontriggering general anesthesia technique that may safely be used in a well-documented MH patient
   c. Quadrupling of end tidal CO_2 ($ETCO_2$), deep metabolic acidosis, and hyperkalemic cardiac arrest indicate fulminant MH
   d. Discontinuing triggering agent, cooling, hyperventilating, treating high potassium and arrhythmias, and the use of dantrolene sodium are part of the treatment for MH
   e. All of the above

6. Which of the following statements is true about postoperative nausea and vomiting (PONV)?
   a. The most effective way to prevent PONV is to use a light, short, general anesthesia
   b. NSAIDs, narcotics, and epidural PCA are the best way to treat PONV
   c. Patients with a positive history of PONV and/or motion sickness, general anesthesia with inhalational agents lasting longer than 3 hours, orchiopexy, hernia repair, and laparoscopic surgery are most likely to develop PONV
   d. In most studies, a combination of dexamethasone and antiserotonin antagonist prove to be the least effective in treating PONV
   e. Propofol total intravenous anesthesia (TIVA) does not have any preventative effect on PONV

7. The advantages of regional anesthesia for GU surgery, as compared to general anesthesia, are as follows:
   a. Regional anesthesia decreases the odds of blood transfusion by 50%, pneumonia by 39%, respiratory depression by 59%, MI by 33%, DVT by 44%, PE by 55%, and renal failure by 43%
   b. Regional anesthesia attenuates the body's stress response, decreases hypercoagulability, and preserves perioperative immune function
   c. Regional anesthesia decreases length of stay in the PACU, provides superior postoperative pain control, and increases patient satisfaction
   d. Contraindications for regional anesthesia are cardiac outflow tract obstruction (IHSS and aortic stenosis), the anticoagulated patient (when INR ≥1.4), skin infection, sepsis, allergy to local anesthetic, and shock
   e. All of the above

8. Which of the following statements are true about the pathophysiology of pneumoperitoneum (CO_2 insufflation) under general anesthesia?
   a. It increases intraabdominal pressure (IAP) and decreases cardiac output and functional residual capacity (FRC) of the lungs. It produces drops in body temperature (more pronounced in elderly patients)
   b. The increased IAP and hypercapnia activates the renin-angiotensin-aldosterone axis through a release of catecholamines and vasopressin
   c. Insufflation of CO_2 at 15 mm Hg lowers the FRC, exacerbates the ventilation/perfusion (V/Q) mismatch, and increases intrapulmonary shunting with hypoxia in COPD patients
   d. Cerebral blood flow and intracranial pressure (ICP) increase significantly while the splanchnic, hepatic, and renal blood flows are reduced. All these effects

are prevented by using CO_2 inflating pressures of 9–12 mm Hg
e. All of the above

9. Which one of the following statements is false regarding the Trendelenburg position?
   a. The steep Trendelenburg position (30–45 degrees) exaggerates complications during laparoscopic/robotic surgery, including nerve injuries, compartment syndrome, rhabdomyolysis, dermal injuries, and eye injuries
   b. Intraocular neuropathy (ION) due to choroidal vasodilation and increased secretion of aqueous humor can be prevented by minimizing the degree of Trendelenburg position (to 20–30 degrees)
   c. A lesser (16 degrees) Trendelenburg position is insufficient to provide surgical advantage (e.g., moving bowels away from the pelvis, etc.)
   d. Nonslip pads are effective in preventing patient sliding in Trendelenburg position
   e. A steep Trendelenburg position combined with lithotomy may put undue pressure on the patient's calves and legs

10. Which of the following is a true statement regarding shoulder pain as a postoperative complication of pneumoperitoneum (CO_2 insufflation)?
    a. The most successful ways to treat post-CO_2 insufflation shoulder pain are filling the abdomen with saline solution at the end of surgery or using the Valsalva maneuver at the end of the procedure
    b. It is theorized that shoulder pain is secondary to CO_2 entrapment under the diaphragm, with cervical nerve stimulation and referred pain to C4
    c. Abdominal wall lifters (AWL) are recommended as the most useful method to prevent postoperative shoulder pain
    d. b and c
    e. All of the above

Answers

1. **c.** The patient's preexisting cardiac and pulmonary conditions are the two most common risks for anesthetic morbidity and mortality. Additionally, increasingly prevalent significant risks include morbid obesity and obstructive sleep apnea.
2. **e.** Deciding whether to do surgery in an ambulatory or an inpatient setting should be an individualized decision, based on close cooperation between the patient's primary care physician (PCP), surgeon, and anesthesiologist. Several studies report factors influencing morbidity and mortality in ambulatory surgery on the super-obese: BMI >53, inability to walk over 200 feet, history of deep vein thrombosis (DVT), history of OSA, coexisting medical conditions, and type of surgical procedure. However, ambulatory surgeries of all kinds are routinely done on morbidly obese patients without undue complications or hospital admissions.

   Morbid obesity is defined as BMI ≥40 kg/m^2. Obstructive sleep apnea is often associated with morbid obesity. Since the numbers of morbidly obese patients are continually increasing, obstructive sleep apnea cases are similarly increasing. Patients should be encouraged to use CPAP and/or BiPAP continuously preoperatively and postoperatively. There are certain benefits in the preoperative period to the use of CPAP or BiPAP, specifically an increase in the pharyngeal area, decrease of tongue volume (which occurs in about 4–6 weeks of therapy), improved ventilatory drive, and improvement of most cardiac parameters. Furthermore, recent studies have suggested the utility of CPAP/BiPAP for several days postoperatively when the patient's condition might worsen at home.
3. **d.** ASA III patients have severe systemic disease, involving more than one major body system. They are in no immediate danger of death, but they have some functional limitations (e.g., stable angina, coronary heart failure [CHF], old heart attack, poorly controlled hypertension and diabetes, morbid obesity, chronic renal failure).
4. **d.** A hyperreactive airway can be anticipated by taking a thorough history and physical. Patients with bronchial asthma (or with a history of it), obesity, or COPD, smokers, patients with atopies (e.g., eczema), or those with recent upper respiratory infections (within 4–6 weeks) frequently present either with a hyperreactive airway or with an overt asthmatic condition. Their usual medications, such as β_2-agonists (e.g., albuterol) and anticholinergics (e.g., ipratropium), should be used preoperatively. Most importantly, an adequate depth of anesthesia should be achieved before manipulating the airway with endotracheal intubation or before patient positioning and any surgical manipulation. The same principle applies when extubating these patients. In this patient population, regional anesthesia techniques are preferable, whenever feasible.
5. **e.** All inhalational anesthetics, except N_2O, can trigger MH. Succinylcholine (SCH) is a very frequent trigger. Safe anesthetic agents include N_2O, barbiturates/IV anesthetics, all narcotics, and all antianxiety medications. MH can begin during administration of anesthetic agents, or it may occur postoperatively. To diagnose MH, one should consider both clinical presentation and laboratory data. One of the most consistent clinical indicators is an unanticipated increase (tripling or quadrupling) of $ETCO_2$ when minute ventilation is normal.

   Treatment for MH begins by immediately discontinuing the triggering agent. Hyperventilate with 100% oxygen. Treat with IV 2.5 mg/kg dantrolene sodium (because this solution does not have significant side effects, it should be used for all cases in which MH is suspected). Treat acidosis with bicarbonate; treat hyperkalemia with glucose, insulin, and calcium; and treat hyperthermia with cooling (nasogastric lavage, rectal lavage, intraperitoneal lavage, surface cooling – to an end point of 38°C). Avoid calcium channel blockers (use other antiarrhythmics). Carefully monitor serum potassium; measure creatine phosphokinase (a good measure of muscle destruction) every 6 hours until decreased (though in severe MH, high creatine phosphokinase might last for 2 weeks). Follow coagulation

profile because disseminated intravascular coagulation may occur. Check serial ABG, electrolytes, blood, and urine myoglobin.

6. **c.** The most effective way to prevent PONV is to use a propofol-based TIVA and to preferentially avoid inhalational anesthetics, N_2O (which causes a 30% increase in PONV), and unnecessary sedatives. Propofol TIVA proves especially useful in patients at higher risk for PONV (those with a history of motion sickness or previous PONV).

   Various antiemetic medications are used to treat PONV. One group of antiemetics works by antagonizing neurotransmitters at various receptor sites (e.g., dopamine, histamine, serotonin, or cholinergic-muscarinic receptors). These include antihistamines (diphenhydramine and promethazine), butyrophenones (droperidol and haloperidol), phenothiazines (chlorpromazine and prochlorperazine), benzamides (metoclopramide), and anticholinergics (scopolamine). Another group works as specific antiserotonin ($5\text{-}HT_3$) antagonists (ondansetron, granisetron, and dolasetron). Dexamethasone is a corticosteroid that works through antiinflammatory and some unknown properties.

   As prophylaxis for PONV, dexamethasone combined with an antiserotonin antagonist proves to be one of the most efficient regimens, if used at induction of general anesthesia. For treatment of PONV, combinations of antiemetics seem to be more efficient (through their additive effect) than single medications. In our experience, however, when everything else fails, one of the best rescue medications is haloperidol 1.0 mg to 1.5 mg used intramuscularly (an IV dose is too short acting), which provides >15 hours of intense antiemetic effect without excessive sedation or any hallucinations.

7. **e.** All of the statements are true. A preponderance of outcome data suggest that regional anesthesia improves patient morbidity and mortality, as compared with general anesthesia. Regional anesthesia can be divided into two categories: neuraxial anesthesia (e.g., spinal, epidural, combined spinal/epidural) and peripheral nerve block anesthesia (e.g., pudendal, penile, paravertebral). See text section on "Regional Anesthesia."
8. **e.** All of the statements are true.
9. **c.** A lesser Trendelenburg (16 degrees) position will preserve the surgical advantages while minimizing the risks of the Trendelenburg position (increased intra-abdominal, intrathoracic, intracranial, and intraocular pressure). The rest of the statements are true.
10. **a.** Although the mechanism of post-CO_2 insufflation shoulder pain is unclear, it is theorized that it occurs due to CO_2 entrapment under the diaphragm, which produces phrenic nerve irritation and referred pain to C4. Many surgical maneuvers have been described as potential treatment, including low pressure pneumoperitoneum and the use of AWL, which is no longer recommended. Various postoperative medications (e.g., NSAIDS, narcotics, pregabalin) were found to have limited usefulness.

    The most successful methods were abdominal filling with saline solution at the end of surgery or the use of the Valsalva maneuver in Trendelenburg position at the end of surgery (eliminates intraabdominal CO_2), which yields very good results. At our institution, we routinely use the Valsalva maneuver at the end of all laparoscopic/robotic surgeries with excellent results.

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7 Infectious Complications of Urologic Surgery

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CHAPTER OUTLINE

Antimicrobial Prophylaxis in Urologic Surgery
Endourologic Procedures
Open, Laparoscopic, and Robotic Urologic Surgery
Special Consideration: Heart Valves, Prostheses
Management of Surgical Infections
Surgical Site Infections
Intraabdominal Infections
Postoperative Urinary Tract Infections
Sepsis: Early Recognition and Treatment
Antibiotic Resistance
***Clostridium difficile* Colitis**
Special Considerations
Prostate Biopsy
Inflatable Penile Prostheses
Conclusion
Chapter 7 Questions and Answers

KEY POINTS

1. The duration of antimicrobial prophylaxis should extend throughout the period when bacterial invasion is facilitated and/or likely to establish an infection.
2. Prophylaxis should begin within 60 minutes of the surgical incision (120 minutes for intravenous fluoroquinolines and vancomycin) and generally should be discontinued within 24 hours.
3. American Heart Association no longer recommends antimicrobial prophylaxis for genitourinary surgery solely to prevent infectious endocarditis.
4. Surgical site infections can be reduced by appropriate antibiotics prophylaxis, surgeon hand antiseptic, patient skin preparation, and hair removal.
5. The mainstay management of intraabdominal infections remains initial fluid resuscitation, antibiotic therapy, and drainage of infectious fluid collections .
6. UTIs are the most common type of nosocomial infection, and are frequently postoperative in nature, most commonly the result of manipulating the urinary tract or having an indwelling catheter.
7. Increasing antibiotic resistance and a lack of new antibiotics in the near future call for a variety of coordinated strategies in an effort of antibiotic stewardship.
8. Early recognition and management of sepsis optimizes outcome.
9. Aims to reduce the overuse of antimicrobial agents in conjunction with urologic surgery may reduce antibiotic resistance and limit C. difficile colitis.
10. The appropriate use of antimicrobial prophylaxis in an individual patient requires not only consideration of guidelines but also a comprehensive evaluation of the patient's specific circumstances.

Infectious complications in urologic surgery range from asymptomatic urinary tract infection (UTI) to sepsis and comprise some of the most feared and life-threatening situations in current urologic practice. In this chapter we focus on appropriate antibiotics for surgical and procedural prophylaxis and supporting guidelines, surgical site infections and postoperative UTIs, early recognition and treatment of sepsis, and management of intraabdominal infections. Special consideration is also given to the emerging role of antibiotic resistance, *Clostridium difficile* colitis, and antibiotic stewardship. Emphasis is placed on identification of early postoperative events that could lead to infectious complications in order to achieve a prompt diagnosis and reduce morbidity and mortality.

Antimicrobial Prophylaxis in Urologic Surgery

Infectious complications, including surgical site infections and UTIs, are major sources of postoperative morbidity. Surgical site infections complicate up to 5% of

clean extra-abdominal operations and up to 20% of intraabdominal procedures. UTIs are the most common type of nosocomial infection and are frequently postoperative in nature. Surgical site infections almost double the direct costs of hospitalization, and patients with surgical site infections are more likely to be readmitted, require a stay in the intensive care unit, and suffer mortality. Antimicrobial prophylaxis is an important preventative measure and is a modifiable component of a program to reduce postoperative infections. The American Urologic Association (AUA) published a best practice policy statement on urologic surgery antimicrobial prophylaxis in 2008, which has been updated as recently as 2014.[1] The AUA highlights five principles of surgical antimicrobial prophylaxis:

1. Surgical antimicrobial prophylaxis is the periprocedural systemic administration of an antimicrobial agent intended to reduce the risk of postprocedural local and systemic infections.
2. The potential benefit of surgical antimicrobial prophylaxis is determined by three considerations: patient-related factors (ability of the host to respond to bacterial invasion), procedural factors (likelihood of bacterial invasion at the operative site), and the potential morbidity of infection.
3. Surgical antimicrobial prophylaxis is recommended only when the potential benefit exceeds the risks and anticipated costs.
4. The antimicrobial agent used for prophylaxis should be effective against the disease-relevant bacterial flora characteristic of the operative site. Cost, convenience, and safety of the agent also should be considered.
5. The duration of surgical antimicrobial prophylaxis should extend throughout the period in which bacterial invasion is facilitated and/or is likely to establish an infection.

A surgical wound classification has been developed to help clinicians identify and describe the degree of bacterial contamination of surgical wounds at the time of surgery (Table 7.1). Because of its predictive value, wound classification plays a valuable role in driving quality-improvement initiatives that incorporate risk-adjusted outcomes. All procedures entering the urinary tract are considered "clean contaminated." The likelihood of bacterial invasion is increased if bacteriuria is present or wound preparation and sterile surgical technique are not applied.

ENDOUROLOGIC PROCEDURES

Antimicrobial prophylaxis for urologic surgery is stratified by lower tract and upper tract instrumentation, along with patient risk factors (Table 7.2). Simple cystoscopy has traditionally been a procedure that does not warrant routine antimicrobial prophylactics. Although the literature is not conclusive, it appears there is limited evidence for the use of antibiotics for ambulatory patients who undergo cystoscopy without risk factors such as advanced age, smoking, anatomic anomalies, steroid use, decreased immune function, and urethral catheters.[2–5] In a study of 3108 patient cystoscopies without antibiotic prophylaxis, 673 (22%) had asymptomatic bacteriuria and 2435 (78%) had sterile urine. A febrile UTI developed within 30 days of cystoscopy in 59 patients (1.9%). Therapy before outpatient flexible cystoscopy does not appear necessary in patients who have no clinical signs or symptoms of acute UTI, including bacteriuria.[6] Guideline recommendations for cystoscopy with manipulation including transurethral resection of bladder tumor and prostate, include antimicrobial prophylaxis. Although prophylactic antibiotics have been shown to decrease the incidence of post-TURP bacteriuria, high fever, bacteremia, and additional antibiotic treatment,[7] the prescribing patterns of urologists vary significantly prior to TURP with low compliance to guidelines.[8] Berry and Barratt conducted a meta-analysis of 32 randomized controlled trials evaluating antimicrobial prophylaxis in TURP patients, including 4260 patients.[9] The authors found antibiotic prophylaxis significantly decreases the incidence of bacteriuria and clinical septicemia in men with preoperative sterile urine undergoing TURP. Taken together, these studies highlight (1) the need for preoperative urine culture when feasible, (2) that a single dose of perioperative antibiotics appears sufficient to decrease infectious risk, and (3) that maintaining closed urinary drainage and minimizing drainage may reduce postoperative infection rates. Even

Table 7.1 Surgical Wound Classification

Surgical Wound Classification	
Clean	■ Uninfected operative wound where no inflammation is encountered and respiratory, GI, genital, and urinary tracts are not entered ■ Wounds are primarily closed, and a drain (if needed) is connected to a closed system. ■ Risk of infection: 2% or lower
Clean contaminated	■ Operative wound that enters the respiratory, GI, genital, or urinary tract under controlled conditions without unusual contamination when no infection or major break in technique has occurred ■ Risk of infection: 2–8%
Contaminated	■ Open, fresh, accidental wound from surgery with a major break in sterile technique or gross spillage from GI tract; incision in which acute, nonpurulent inflammation is encountered (including necrotic tissue without evidence of purulent drainage, such as dry gangrene) ■ Risk of infection: 5–15%
Dirty-infected	■ Old traumatic wounds with retained devitalized tissue; procedures with existing clinical infection (purulence already present in wound) or perforated viscera ■ Risk of infection: greater than 30%

Table 7.2 Recommended Antimicrobial Prophylaxis for Urologic Procedures

Procedure	Organisms	Prophylaxis Indicated	Antimicrobial(s) of Choice	Alternative Antimicrobial(s)	Duration of Therapy*
Lower Tract Instrumentation					
Removal of external urinary catheter	GU tract†	If risk factors‡,§	■ Fluoroquinolone¶ ■ TMP-SMX¶	■ Aminoglycoside (aztreonam¥) ± ampicillin¶ ■ 1st-/2nd-gen. cephalosporin¶ ■ Amoxicillin/clavulanate¶	=24 hours¶
Cystography, urodynamic study, or simple cystourethroscopy	GU tract	If risk factors§	■ Fluoroquinolone ■ TMP-SMX	■ Aminoglycoside (aztreonam¥) ± ampicillin ■ 1st-/2nd-gen. cephalosporin ■ Amoxicillin/clavulanate	=24 hours
Cystourethroscopy with manipulation|	GU tract	All	■ Fluoroquinolone ■ TMP-SMX	■ Aminoglycoside (aztreonam¥) ± ampicillin ■ 1st-/2nd-gen. cephalosporin ■ Amoxicillin/clavulanate	=24 hours
Prostate brachytherapy or cryotherapy	Skin	Uncertain	■ 1st-gen. cephalosporin	■ Clindamycin**	=24 hours
Transrectal prostate biopsy	Intestine††	All	■ Fluoroquinolone ■ 1st-/2nd-/3rd-gen. cephalosporin	■ TMP-SMX ■ Aminoglycoside (aztreonam¥)	=24 hours
Upper Tract Instrumentation					
Shock-wave lithotripsy	GU tract	If risk factors	■ Fluoroquinolone ■ TMP-SMX	■ Aminoglycoside (aztreonam¥) ± ampicillin ■ 1st-/2nd-gen. cephalosporin ■ Amoxicillin/clavulanate	=24 hours
Percutaneous renal surgery	GU tract and skin‡‡	All	■ 1st-/2nd-gen. cephalosporin ■ Aminoglycoside (aztreonam¥) + metronidazole or clindamycin	■ Ampicillin/sulbactam ■ Fluoroquinolone	=24 hours
Ureteroscopy	GU tract	All	■ Fluoroquinolone ■ TMP-SMX	■ Aminoglycoside (aztreonam¥) ± ampicillin ■ 1st-/2nd-gen. cephalosporin ■ Amoxicillin/clavulanate	=24 hours
Open or Laparoscopic Surgery					
Vaginal surgery (includes urethral sling procedures)	GU tract, skin and Grp B *Strep.*	All	■ 1st-/2nd-gen. cephalosporin ■ Aminoglycoside (aztreonam¥) + metronidazole or clindamycin	■ Ampicillin/sulbactam ■ Fluoroquinolone	=24 hours
Without entering urinary tract	Skin	If risk factors	■ 1st-gen. cephalosporin	■ Clindamycin	Single dose
Involving entry into urinary tract	GU tract and skin	All	■ 1st-/2nd-gen. cephalosporin ■ Aminoglycoside (aztreonam¥) + metronidazole or clindamycin	■ Ampicillin/sulbactam ■ Fluoroquinolone	=24 hours
Involving intestine§§	GU tract, skin and intestine	All	■ 2nd/3rd gen. cephalosporin ■ Aminoglycoside (aztreonam¥) + metronidazole or clindamycin	■ Ampicillin/sulbactam ■ Ticarcillin/clavulanate ■ Piperacillin/tazobactam ■ Fluoroquinolone	=24 hours
Involving implanted prosthesis	GU tract and skin	All	■ Aminoglycoside (aztreonam¥) + 1st/2nd gen. cephalosporin or vancomycin	■ Ampicillin/sulbactam ■ Ticarcillin/clavulanate ■ Piperacillin/tazobactam	=24 hours

*Additional antimicrobial therapy may be recommended at the time of removal of an externalized urinary catheter.
†GU tract: Common urinary tract organisms are *E. coli, Proteus sp., Klebsiella sp., Enterococcus.*
‡See Table 1 "Patient-related factors affecting host response to surgical infections."
§If urine culture shows no growth prior to the procedure, antimicrobial prophylaxis is not necessary.
¶Or full course of culture-directed antimicrobials for documented infection (which is treatment, not prophylaxis).
¥Aztreonam can be substituted for aminoglycosides in patients with renal insufficiency.
|Includes transurethral resection of bladder tumor and prostate, and any biopsy, resection, fulguration, foreign body removal, urethral dilation or urethrotomy, or ureteral instrumentation including catheterization or stent placement/removal.
**Clindamycin, or aminoglycoside + metronidazole or clindamycin, are general alternatives to penicillins and cephalosporins in patients with penicillin allergy, even when not specifically listed.
††Intestine: Common intestinal organisms are *E. coli, Klebsiella sp., Enterobacter, Serratia sp, Proteus sp., Enterococcus*, and anaerobes.
‡‡Skin: Common skin organisms are *S. aureus*, coagulase negative *Staph. sp.*, Group A *Strep. sp.*
§§For surgery involving the colon, bowel preparation with oral neomycin plus either erythromycin base or metronidazole can be added to or substituted for systemic agents.
Key: gen, generation; GU, genitourinary; TMP-SMX, trimethoprim-sulfamethoxazole.
(Reproduced with permission from Best Practice Policy Statement on Urologic Surgery Antimicrobial Prophylaxis. https://www.auanet.org/education/guidelines/antimicrobial-prophylaxis.cfm#3.)

though guidelines recommend antimicrobial prophylaxis for TURBT, data remain controversial. Studies have shown antibiotics for TURBT in patients with no risk factors for infectious complications may not be necessary where use of antibiotics might be deferred until postoperative infections develop.[10]

Fluoroquinolone and TMP-SMX remain the mainstay prophylactic antibiotic of choice for the majority of endourologic procedures. Ureteroscopy, which is the mainstay for ureteral and renal calculi and a diagnostic procedure for upper tract urothelial tumors, merits antibiotic prophylaxis. For ureteroscopic stone treatment, the postoperative UTI rate is low (<2.5%).[9] Antibiotic prophylaxis significantly reduces the incidence of pyuria and tends to diminish the risk of bacteriuria and UTI.[11] However, recent studies have demonstrated that in patients with a negative baseline urine culture undergoing ureteroscopy for ureteral or renal stones, rates of postoperative UTI and fever were not reduced by preoperative antibiotic prophylaxis, highlighting the need for antibiotic stewardship.[9] A continuous antibiotic low-dose treatment during the entire JJ stent indwelling time does not reduce the quantity or severity of UTIs compared with a peri-interventional antibiotic prophylaxis only.[12] The use of oral peri-stent removal antibiotic prophylaxis is sufficient to prevent symptomatic UTIs in patients who have undergone uncomplicated ureteroscopy for urolithiasis.[13] The judicious use of antibiotics in uncomplicated cases may help lower the incidence of resistant organisms and other complications related to the widespread use of antibiotics. In patients with pyelonephritis secondary to obstructive stones, antimicrobial resistance makes the selection of empiric antibiotic treatment challenging because of discordance between voided urine cultures and those captured at the time of decompression.[14] It is imperative to obtain both voided urine and urine from the kidney to ensure adequate antibiotic coverage. After uncomplicated ureteroscopy for urolithaisis, the use of oral peri-stent removal antibiotic prophylaxis has been found to be sufficient to prevent symptomatic UTIs.[13]

Percutaneous access to the renal collecting system may put the patient at increased risk for bacteremia and sepsis due to traversing the renal parenchyma and merit antimicrobial prophylaxis with a first- or second-generation cephalosporin, or aminoglycoside with metronidazole or clindamycin. Reports have demonstrated a significant risk of postoperative infectious complications including sepsis despite prophylactic antibiotics during PCNL; however, the optimal duration of perioperative antibiotic administration in stone patients remains an area of debate. Antibiotic prophylaxis of patients undergoing percutaneous nephrolithotomy with a negative baseline urine culture is associated with a significant reduction in the rate of postoperative fever (2.5% vs 7.4%, p = 0.040) and other complications.[15] Deshmukh et al. observed comparable rates of immediate fevers after PCNL with no difference in postoperative infections between patients undergoing 24 hours of perioperative antibiotics (consistent with AUA guidelines) versus −7 days of antibiotics after surgery.[16] However, other studies have shown the benefits of prolonged antibiotic prophylaxis. Mariappan et al. prospectively evaluated patients with a stone burden of at least 2 cm or pelvicaliceal dilation and a negative preoperative urine culture who received a 7-day course of ciprofloxacin or standard antibiotics before PCNL.[17] They noted a threefold lower rate of systemic inflammatory response syndrome in patients in the extended antibiotic arm. Multidrug resistant preoperative urine culture has been shown to be significantly predictive of an infectious complication in patients undergoing PCNL compared to the presence of a positive urine culture alone.[18] As such, efforts have focused on curtailing the indiscriminant use of antibiotics and promoting use only when indications for administration are clear. A common finding of these studies remains that no antibiotic prophylaxis regimen will completely eliminate the risk of infection after endoscopic stone surgery.

The incidence of infectious complications after extracorporeal shock wave lithotripsy (ESWL) in patients without risk factors is low.[19] A recent meta-analysis of nine randomized controlled trials assessing the efficiency of antimicrobial prophylaxis for shock wave lithotripsy demonstrated no statistically significant benefit of therapy in terms of reducing postoperative bacteriuria, clinical UTIs, or fever.[20] In a prospective study evaluating the use of targeted antibiotic prophylaxis in preventing UTIs in patients undergoing shock wave lithotripsy, Honey et al. found of the 389 patients included in the determination of the primary outcome, UTI developed in only one (0.3%), urosepsis did not develop in any patients, and asymptomatic bacteriuria developed in 11 (2.8%), suggesting universal use of antibiotic in ESWL may not be needed.[21]

AUA guidelines do not recommend routine use of antimicrobial prophylaxis during ESWL; however, it may be justified for those with increased risk for infection.[19]

OPEN, LAPAROSCOPIC, AND ROBOTIC UROLOGIC SURGERY

Studies indicate that antimicrobial prophylaxis is most effective when provided prior to the initial surgical incision, which is supported by the Surgical Care Improvement Project (SCIP) sponsored by The Joint Commission. The SCIP measure dictates that prophylactic antibiotic must be received within 1 hour prior to incision (or within 2 hours before incision if vancomycin is required for prophylaxis). This allows the establishment of bactericidal tissue and serum levels at the time of skin incision to reduce the risk of infection. A landmark study in 1992 consisting of 2847 surgery patients found that the lowest incidence of postoperative infection was associated with antibiotic administration during the 1 hour prior to surgery.[22] The risk of infection increased progressively with greater time intervals between administration and surgical incision. Results of this study showed lowest infection rates (less than 1%) for patients undergoing surgery when an antimicrobial dose was administered within 1 hour before the incision. Patients who received the antibiotics too soon (more than 2 hours prior to incision) had an infection rate of 3.8%. Likewise, patients who received the antibiotics 3 hours after incision had an infection rate of 3.3%.

Antimicrobial prophylaxis can be stratified based on entry into the urinary tract or intestine. Surgery without entry into the urinary tract includes a variety of invasive and superficial urologic procedures. Results in a cohort of 83 patients undergoing transabdominal radical

nephrectomy randomized to a single dose of intravenous cephalosporin versus no perioperative prophylaxis revealed a significantly lower overall infection rate in the treatment group (8% vs 27%).[23] In a prospective but nonrandomized comparison of 424 hand-assisted laparoscopic nephrectomies with and without antimicrobial prophylaxis (cephalosporin), wound infections occurred significantly more often in patients without prophylaxis (13% vs 5.4%).[24]

In a comprehensive review of the literature regarding surgery with entry into the urinary tract, the authors concluded that the expected rate of febrile UTI is 5–10% without prophylaxis and that antimicrobial prophylaxis would significantly reduce the rate of febrile UTI, to 2–3%.[25] In a randomized controlled trial of 91 men undergoing open prostatectomy, intravenous cefotaxime (compared to no prophylaxis) significantly reduced the incidence of postoperative infection from 46% to 5%.[26]

Although randomized controlled trials (RCTs) involving urologic surgery involving bowel (primarily urinary diversion, with or without cystectomy) have not been reported, supportive literature from neighboring surgical specialties confirm the benefit of antimicrobial prophylaxis in the setting of surgery involving intestinal components. Tailoring preoperative antimicrobial prophylaxis during radical cystectomy to broader, culture-directed antimicrobial prophylaxis, based on institutional data to include antifungal coverage, has been shown to decrease postoperative infections.[27] Additionally, longer durations of antibiotic coverage beyond 24 hours appear not to improve rates of septic complications during cystectomy.[28]

SPECIAL CONSIDERATION: HEART VALVES, PROSTHESES

Patients with preexisting implanted surgical hardware, such as artificial joints and prosthetic heart valves, are of particular interest because this foreign material may become hematogenously seeded from bacteremia induced during surgical manipulation. These infections are frequently difficult to treat and often require surgical removal of the infected material. Antibiotic prophylaxis for the prevention of infective endocarditis is not recommended in patients undergoing urologic procedures, even in patients with the highest risk of heart conditions (see Chapter 3).

Antimicrobial prophylaxis is not indicated for urologic patients on the basis of orthopedic pins, plates, and screws, nor is it routinely indicated for most urologic patients with total joint replacements on that basis alone.[1] However, antimicrobial prophylaxis intended to reduce the risk of hematogenous total joint infection is recommended in patients who meet both sets of criteria shown in Table 7.3. The recommended antimicrobial regimen in these patients include a single systemic level dose of a quinolone (e.g., ciprofloxacin, 500 mg; levofloxacin, 500 mg; ofloxacin, 400 mg) orally 1–2 hours preoperatively or ampicillin 2 g IV (or vancomycin 1 g IV over 1–2 hours in patients allergic to ampicillin) plus gentamicin 1.5 mg/kg IV 30–60 minutes preoperatively. Alternative culture-specific antibiotics may also be considered in some cases.

Management of Surgical Infections

SURGICAL SITE INFECTIONS

Surgical site infections (SSIs) are associated with substantial morbidity and mortality, prolonged hospital stay, and increased cost. The US Centers for Disease Control and Prevention (CDC) has developed criteria that define an SSI as an infection related to an operative procedure that occurs at or near the surgical incision within 30 days of the procedure or 90 days if prosthetic material is implanted at surgery. SSIs are the most common nosocomial infection, accounting for 38% of nosocomial infections. However, the overall risk of SSI is low; it is estimated that SSIs develop in 2–5% of the more than 30 million patients undergoing surgical procedures each year (i.e., 1 in 24 patients who undergo inpatient surgery in the United States has a postoperative SSI).[29] SSIs complicate up to 5% of clean extraabdominal operations and up to 20% of intraabdominal procedures.[30] SSIs almost double the direct costs of hospitalization, and patients with SSIs are more likely to be readmitted, require

Table 7.3 Criteria for Antibiotic Prophylaxis in Total Joint Replacements

Increased Risk of Hematogenous Total Joint Infection	Increased Risk of Bacteremia Associated With Urologic Procedures
Patients during the first 2 years after prosthetic joint replacement Immunocompromised patients with prosthetic joint replacements ■ Inflammatory arthropathies (e.g., rheumatoid arthritis, systemic lupus erythematosus) ■ Drug-induced immunosuppression ■ Radiation-induced immunosuppression Patients with prosthetic joint replacements and comorbidities ■ Previous prosthetic joint infections ■ Malnourishment ■ Hemophilia ■ HIV infection ■ Diabetes ■ Malignancy	Any stone manipulation (includes shock-wave lithotripsy) Any procedure with transmural incision into urinary tract (does not include simple ligation with excision or percutaneous drainage procedure) Any endoscopic procedures of upper tract (ureter and kidney) Any procedure that includes bowel segments Transrectal prostate biopsy Any procedure with entry into the urinary tract (except for urethral catheterization) in individuals with higher risk of bacterial colonization: ■ Indwelling catheter or intermittent catheterization ■ Indwelling ureteral stent ■ Urinary retention ■ History of recent/recurrent urinary tract infection or prostatitis ■ Urinary diversion

(Reproduced with permission from Best Practice Policy Statement on Urologic Surgery Antimicrobial Prophylaxis. https://www.auanet.org/education/guidelines/antimicrobial-prophylaxis.cfm#3)

stay in the intensive care unit, and suffer mortality.[31] Using the Healthcare Cost and Utilization Project National Inpatient Sample, de Lissovoy et al. evaluted 723,490 surgical hospitalizations, of which 6891 cases of SSI were identified (1%). On average, SSI extended length of stay by 9.7 days while increasing cost by $20,842 per admission. From the national perspective, these cases of SSI were associated with an additional 406,730 hospital-days and hospital costs exceeding $900 million. An additional 91,613 readmissions for treatment of SSI accounted for a further 521,933 days of care at a cost of nearly $700 million.[32]

Clinical criteria for defining SSI include one or more of the following:[33] (1) a purulent exudate draining from a surgical site, (2) a positive fluid culture obtained from a surgical site that was closed primarily, (3) a surgical site that is reopened in the setting of at least one clinical sign of infection (pain, swelling, erythema, warmth) and is culture positive or not cultured, and (4) the surgeon's diagnosis of infection. SSIs are classified as incisional or organ/space. Incisional SSIs are further divided into superficial, those involving only the skin or subcutaneous tissue, or deep, those involving deep soft tissues of an incision. Organ/space SSIs account for one-third of all SSIs, but are associated with more than 90% of deaths related to SSIs.

In addition to antibiotic prophylaxis, several other measures may decrease rates of SSIs including surgeon hand antiseptic, patient skin preparation, and hair removal. In a Cochrane database review of preoperative skin antiseptics for preventing surgical wound infections after clean surgery, the authors found evidence that preoperative skin preparation with 0.5% chlorhexidine in methylated spirits was associated with lower rates of SSIs following clean surgery than alcohol-based povidone iodine paint.[34] In a cohort of patients submitted to open prostatectomy, the type of antiseptic did not affect SSI risk (0.5% povidone-iodine or chlorhexidine in an alcohol base).[35]

The alcohol-based hand rub has been shown to be more efficacious for surgical antisepsis when compared to conventional surgical scrub.[36] Whether this translates into a decrease in SSI is not clear. In a literature review of surgical hand antisepsis to reduce surgical site infection, alcohol rubs used in preparation for surgery by the scrub team are as effective as aqueous scrubbing in preventing SSIs, but the analysis data were limited by study methods and quality.[37] Avagard Hand Antiseptic (3M, St. Paul, MN) has been shown to provide comparable hand antisepsis to the traditional surgical scrub in a variety of pediatric urologic procedures. Avagard Hand Antiseptic was noted to be superior to the surgical hand scrub in cost-effectiveness and time efficiency.[38]

Preoperative hair removal has been used to prevent surgical site infections; however, a meta-analysis of 19 randomized controlled trials confirmed the absence of any benefit of depilation to prevent surgical site infection, as well as the higher risk of surgical site infection when shaving is used for depilation.[39]

The proportion of patients developing SSIs depends on the type of surgery. Although SSI rates are low in urologic surgery, minimally invasive surgery compared to open surgery is significantly associated with reduced rates of SSIs, including prostatectomy (1.0% vs 2.4%)[40,41] and partial nephrectomy (0.54% vs 1.3%).[42] The SSI rate in minimally invasive adrenal and renal surgery is low (1.6%), and reports have suggested that antimicrobial prophylaxis may be avoided in this clean category minimally invasive surgery. On-demand use of antibiotics in the renal and adrenal surgery seem to be sufficient for perioperative infectious management.[43] In 556 patients undergoing urologic laparoscopic procedures, 14 surgical site infections (2.5%) were identified at mean postoperative day 21.5.[44] Of the 14 surgical site infections, 10 (71.4%) were located at a specimen extraction site. Infection is associated with prolonged operative time and increasing body mass index.

In a study of 200 patients who underwent either inguinal or scrotal surgery, both of which are classified as clean surgery, the overall SSI infection rate was 3.5%. However, the frequencies of SSI were 6.5% in the patients with urologic inguinal surgery and 1.6% in those with scrotal surgery even though all patients received a first- or second-generation cephalosporin as antimicrobial prophylaxis. The frequency of SSI in the patients with urologic inguinal surgery was not negligible even though it is considered a clean operation, and this highlights the need for SSI prevention.[45]

Implanted urologic devices are at increased risk for infection. Haraway et al. evaluated 136 patients who underwent sacral neuromodulation implantation and found 5.9% experienced infections that required device explantation. Preoperative antibiotic selection was a significant factor in preventing subsequent infection and explantation where cefazolin was less effective in preventing infection compared with the other antibiotic regimens.[46] Implanted seeds do not appear to have the same risk of infection. In 826 patients with localized prostate cancer who underwent a transperineal (125)I brachytherapy, all of who received antimicrobial prophylaxis, 0.73% of patients had a perioperative infection.[47] Bacteriuria and preoperative hair removal were risk factors of perioperative infection with statistical significance ($p = 0.007$ and $p = 0.004$, respectively), highlighting additional measures to prevent perioperative infectious complications.

Historically, preoperative mechanical bowel preparation has been considered the standard of care for patients undergoing radical cystectomy with urinary diversion. Recent data have shown the use of mechanical bowel preparation for patients undergoing radical cystectomy with an ileal conduit or orthotopic neobladder does not seem to impact the rates of perioperative infections or wound and bowel complications.[48,49]

INTRAABDOMINAL INFECTIONS

Intraabdominal infections are the second most common cause of infectious mortality in intensive care units. Complicated intraabdominal infection, which extends into the peritoneal space, is associated with abscess formation and peritonitis. Uncomplicated infection, which involves intramural inflammation of the gastrointestinal tract, may progress to complicated infection if left untreated. Treatment of intraabdominal infections has evolved in recent years because of advances in supportive care, diagnostic imaging, minimally invasive intervention, and antimicrobial therapy. Based on these new advances, evidence-based guidelines for managing patients with intraabdominal infection were prepared by an Expert Panel of the Surgical

Infection Society and the Infectious Diseases Society of America.[50]

Fluid resuscitation is a key initial step in managing intraabdominal postoperative infections. Volume depletion is common in febrile patients and is worsened by poor fluid intake because of nausea and/or vomiting and in the presence of ileus induced by intraabdominal inflammation. Patients should undergo rapid restoration of intravascular volume and additional measures as needed to promote physiologic stability. For patients with septic shock, such resuscitation should begin immediately when hypotension is identified. For patients without evidence of volume depletion, intravenous fluid therapy should begin when the diagnosis of intraabdominal infection is first suspected. Antibiotic therapy involves the administration of parenteral empirical antibiotics and should be initiated once a patient receives a diagnosis of an intraabdominal infection or once such an infection is considered likely. For patients with septic shock, antibiotics should be administered as soon as possible. They should be initiated before abscess drainage and concluded when all systemic signs of sepsis have resolved. Because abscess fluid usually contains a mixture of aerobic and anaerobic organisms, initial empiric therapy must be directed against both types of microbes. This may be accomplished with antibiotic combination therapy or with broad-spectrum, single-agent therapy. Specific therapy is then guided by the results of cultures retrieved from the abscess. In patients who are immunosuppressed, candidal species may play an important pathogenic role, and treatment with antifungals may be indicated. Fluconazole is an appropriate choice for treatment if *Candida albicans* is isolated. For fluconazole-resistant *Candida* species, therapy with an echinocandin is appropriate. Because of toxicity, amphotericin B is not recommended as initial therapy.

Drainage of infectious fluid collections is mandatory and is the first line of defense against progressive sepsis. Percutaneous computed tomography (CT)-guided catheter drainage has become the standard treatment of most intraabdominal abscesses and is preferable to surgical drainage. Patients with diffuse peritonitis should undergo an emergency surgical procedure as soon as is possible, even if ongoing measures to restore physiologic stability need to be continued during the procedure. Percutaneous drainage avoids anesthesia and possibly difficult laparotomy, prevents the possibility of wound complications from open surgery, and may reduce the length of hospitalization. It also obviates the possibility of contaminating other areas within the peritoneal cavity.

Cultures should be performed from one specimen, provided it is of sufficient volume (at least 1 mL of fluid or tissue, preferably more) and is transported to the laboratory in an appropriate transport system. For optimal recovery of aerobic bacteria, 1–10 mL of fluid should be inoculated directly into an aerobic blood culture bottle. In addition, 0.5 mL of fluid should be sent to the laboratory for Gram stain and, if indicated, fungal cultures. If anaerobic cultures are requested, at least 0.5 mL of fluid or 0.5 g of tissue should be transported in an anaerobic transport tube. Alternatively, for recovery of anaerobic bacteria, 1–10 mL of fluid can be inoculated directly into an anaerobic blood culture bottle. Susceptibility testing for *Pseudomonas, Proteus, Acinetobacter, Staphylococcus aureus*, and predominant *Enterobacteriaceae*, as determined by moderate-to-heavy growth, should be performed, because these species are more likely than others to yield resistant organisms.

After drainage, clinical improvement should occur within 48–72 hours. Lack of improvement within this time frame mandates repeat CT scanning to check for additional abscesses. Surgical drainage becomes mandatory if residual fluid cannot be evacuated with catheter irrigation, manipulation, or additional drain placement. Contraindications to surgical correction of abdominal abscesses are based on the patient's comorbidities and on the individual's ability to tolerate surgery. The surgical approach may be either laparoscopic or open. Transperitoneal exploration is indicated for multiple abscesses not amenable to CT-guided drainage, such as interloop collections or an enteric fistula feeding the abscess. In the latter situation, draining the abscesses with an enteric communication may be possible for several days before a laparotomy is performed to control the fistula.

Criteria for removal of percutaneous catheters include resolution of sepsis signs, minimal drainage from the catheter, and resolution of the abscess cavity as demonstrated by ultrasonography or CT. Antimicrobial therapy of established infection should be limited to 4–7 days, unless it is difficult to achieve adequate source control. Longer durations of therapy have not been associated with improved outcome. In patients who have persistent or recurrent clinical evidence of intraabdominal infection after 4–7 days of therapy, appropriate diagnostic investigation should be undertaken. This should include CT or ultrasound imaging. Antimicrobial therapy effective against the organisms initially identified should be continued. Persistent drainage usually reflects the presence of an enteric fistula, and a CT scan with contrast should be performed. Frequently, this fistula can be documented by sinography.

Complications of percutaneous drainage include bleeding or inadvertent puncture of the gastrointestinal tract.

POSTOPERATIVE URINARY TRACT INFECTIONS

UTIs are the most common type of nosocomial infection and are frequently postoperative in nature, most commonly the result of manipulating the urinary tract or having an indwelling catheter.[51]

Postoperative UTIs are observed more commonly after major urologic surgery compared with endoscopic procedures, especially after prostate surgery. There are two critical times for the development of infectious complications following prostatic surgery: the perioperative period and the time of catheter removal where 25% of men will have a positive urine culture.[52] In a study of 729 consecutive radical prostatectomies, UTI was observed less frequently among patients receiving short-term antibiotic therapy (3.1% vs. 7.3%) after catheter removal compared with those not receiving antibiotics ($p = 0.019$).[53] One would need to prescribe antibiotic therapy to 24 patients to prevent one case of UTI.[53]

A positive urine culture is a very common finding in patients with an orthotopic bladder, occurring in >50% of patients.[54] Symptomatic UTI, however, occurs at lower rates but remains a common complication after neobladder

reconstruction, usually occurring within the first 3 months of surgery.[55]

SEPSIS: EARLY RECOGNITION AND TREATMENT

Development of sepsis after surgery imposes a significant clinical resource and health-care burden. Factors associated with the development of postoperative sepsis are frequently procedure dependent and are more common with bacteriuria, but also patient comorbidities such as diabetes and hypertension, as well as smoking history along with race, age, hospital size, and hospital location, impact sepsis rates. The American College of Chest Physicians and Society of Critical Care Medicine originally classified the continuum of an inflammatory response to microorganisms as systemic inflammatory response syndrome, sepsis, severe sepsis, and septic shock. These definitions have recently been modified in a consensus by the European Society of Intensive Care Medicine and the Society of Critical Care Medicine and no longer employ the term *systemic inflammatory response syndrome*.[56] The change in definitions was prompted by the increased recognition of the pathobiology and need to clinically define sepsis and septic shock. In addition, a new score called quickSOFA (Sequential Organ Failure Assessment score: qSOFA) was devised and validated for the clinical criteria of sepsis.[57] Early recognition and management of sepsis optimizes outcome. Therefore patients in whom this problem is suspected after genitourinary surgery should be prioritized and receive timely care. To diagnose sepsis and septic shock as early as possible, it is necessary to have clear definitions of infection, organ dysfunction, and global tissue hypoxia and to recognize the clinical and laboratory findings that are indicative of these conditions (Table 7.4).

Fever is the most common manifestation of sepsis. The absence of fever and sepsis-induced hypothermia is more likely in patients at the extremes of age, debilitated patients, patients with chronic alcohol abuse, and patients with uremia.[58] Hypotension is the presenting abnormality in approximately 40% of patients with sepsis. Withdrawal and agitation can be subtle and may be the sole presentations of sepsis in older persons. Immunocompromised patients and those with neutropenia often lack an obvious source of infection.

Appropriate therapy is a continuum of infection management ranging from drainage, such as maintaining an indwelling catheter or opening the nephrostomy tube in cases of percutaneous renal surgery and broad-spectrum antibiotics, to aggressive fluid resuscitation and invasive monitoring with medical management in the intensive care setting until the causative agent is found and eradicated. Published consensus guidelines have been in place to direct the management of septic patients.[59] The guidelines highlight the need for continuous monitoring of vital signs, pulse oximetry, urine output, and initial laboratory testing to assess the severity of global tissue hypoxia and organ dysfunction and should be instituted as soon as possible in patients in whom severe sepsis/septic shock is suspected to facilitate the earliest recognition of this condition.

Early management of sepsis requires respiratory stabilization. Supplemental oxygen should be given to all patients. Mechanical ventilation is recommended when supplemental oxygen fails to improve oxygenation, when respiratory failure is imminent, or when the airway cannot be protected. Perfusion is assessed after respiratory stabilization. Hypotension signifies inadequate tissue perfusion. Clinical signs of hypoperfusion include cold or clammy skin, altered mental status, oliguria or anuria, and lactic acidosis.

After initial respiratory stabilization, treatment consists of fluid resuscitation, vasopressor therapy, infection identification and control, prompt antibiotic administration, and the removal or drainage of the infection source. Early goal-directed therapy is a strategy implemented within 6 hours of suspected sepsis or septic shock. Goals during the first 6 hours of resuscitation are (a) central venous pressure (CVP) 8–12 mm Hg, (b) mean arterial pressure (MAP) ≥65 mm Hg, (c) urine output ≥0.5 mL/kg/hr, and (d) central venous (superior vena cava) or mixed venous oxygen saturation 70% or 65%, respectively. In patients with elevated lactate levels, resuscitation should be targeted to normalize lactate. Crystalloids are the initial fluid of choice in the resuscitation of severe sepsis and septic shock.

Early appropriate antibiotic therapy is associated with improved clinical outcomes. Consensus guidelines recommend antibiotic therapy within 1 hour of suspected sepsis.[59] Initial empiric anti-infective therapy of one or more drugs that have activity against all likely pathogens (bacterial and/or fungal or viral) and that penetrate in adequate concentrations into tissues presumed to be the source of sepsis should be initiated. In septic shock, the initiation of antibiotic therapy within 1 hour increases survival; with each hour antibiotic therapy is delayed, survival decreases by about 8%.[60] The usual bacteria cultured from urinary sources are aerobic gram-negative bacilli and enterococci. Cultures should be drawn as clinically appropriate before antimicrobial therapy if it does not result in significant delay (>45 mins) in the start of antimicrobial(s), including blood, urine, stool (for diarrhea or recent antibiotic use), sputum, and skin and soft tissue culture. At least two sets of blood cultures (both aerobic and anaerobic bottles) should be obtained before antimicrobial therapy with at least one drawn percutaneously and one drawn through each vascular access device, unless the device was recently (<48 hours) inserted. However, blood culture results are negative in 50–65% of patients with sepsis.[18]

Recommended tests include a complete blood count with differential, basic metabolic panel, measurement of lactate and liver enzyme levels, coagulation studies, and urinalysis.

Table 7.4 Terms and Definitions of Sepsis and Septic Shock

Sepsis	Suspected or documented infection and an acute increase of ≥2 SOFA points (a proxy for organ dysfunction)
Septic shock	Sepsis and vasopressor therapy needed to elevate MAP (mean arterial pressure) ≥65 mm Hg and lactate >2 mmol/L (18 mg/dL) despite adequate fluid resuscitation

SOFA; Sequential [Sepsis-related] Organ Failure Assessment
(Reproduced from Singer M, Deutschman CS, Seymour CW, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). JAMA. 2016;315(8):801-10.)

Suspected respiratory infections should be evaluated using chest radiography and arterial blood gas testing to assess hypoxemia and acid–base abnormalities. If disseminated intravascular coagulation is suspected, fibrin degradation products, D-dimer levels, and fibrinogen levels should be measured. Several biologic markers of sepsis such as C-reactive protein, procalcitonin, activated partial thromboplastin time, and interleukin-6 may have diagnostic and prognostic implications, although lack of standardized assays limits their practical use.

Empiric antimicrobial combination therapy should not be administered for more than 3–5 days. De-escalation to the most appropriate single therapy should be performed as soon as the susceptibility profile is known. Duration of antimicrobial therapy is typically 7–10 days; longer courses may be appropriate in patients who have a slow clinical response, undrainable foci of infection, bacteremia with *S. aureus*; some fungal and viral infections, or immunologic deficiencies including neutropenia.

Antibiotic Resistance

Increasing antibiotic resistance and a lack of new antibiotics in the near future call for a variety of coordinated strategies, called "antibiotic stewardship," to improve antibiotic use with the goal of enhancing patient health outcomes and reducing the emergence of resistance to antibiotics.[61] Multidrug-resistant (MDR) uropathogens are increasing in prevalence and may contribute to significant morbidity. Specifically, antibiotic resistance in gram-negative uropathogens is a major global concern. Worldwide, the prevalence of Enterobacteriaceae that produce extended-spectrum β-lactamase or carbapenemase enzymes continues to increase at alarming rates. Likewise, resistance to other antimicrobial agents including aminoglycosides, sulfonamides, and fluoroquinolones is also escalating rapidly. Trimethoprim-sulfamethoxazole (TMP-SMX) resistance rates for *E. coli* UTIs have increased substantially over the last decade to where TMP-SMX is no longer a suitable empirical antimicrobial for UTI in some studies.[62] Similarly, there has been a 10-fold increase in *E. coli* resistance to ciprofloxacin for UTIs and therefore may be an unsuitable empirical therapy for nosocomial UTIs and UTIs in the urology population.[62–64] Recently Teillant et al. studied the ability of antibiotic prophylaxis to prevent infections and deaths from infections for the 10 most common surgeries and blood cancer chemotherapy regimens in the United States, including transrectal prostate biopsy.[65] They calculated the additional number of infections and deaths related to infections that would occur under different scenarios of reduced efficacy of antibiotic prophylaxis and found that in the United States, 38.7% to 50.9% of pathogens causing surgical site infections are resistant to standard prophylactic antibiotics.[65]

Bacterial resistance has major implications for urologic practice, particularly in relation to catheter-associated UTIs and infectious complications following transrectal ultrasonography-guided biopsy of the prostate or urologic surgery. Uropathogenic *E. coli* attach to and invade uroepithelial cells and form intracellular bacterial communities. These aid evasion of the host's immune system and provide some protection against antibiotic exposure. The formation of a quiescent reservoir within the transitional cell layer might contribute to relapsing or persistent infection. Biofilm formation enables the organism to avoid host defenses and resist antibiotic therapy and provides a reservoir for ongoing infection if the catheter is not removed. Transrectal biopsy allows direct transfer of bacteria from the rectum to the prostate, including a potential reservoir of resistance that can be enhanced by prior antibiotic exposure.

Studies evaluating the adherence to society guidelines have shown a reduction in the rate of bacterial resistance and reduced costs without increasing the risk of postoperative infection after urologic procedures.[66] Responding to the challenges of antibiotic resistance will require a multifaceted approach including considered use of current antimicrobial agents, improved diagnostics (including the rapid detection of resistance) and surveillance, better adherence to basic measures of infection prevention, development of new antibiotics, and research into nonantibiotic treatment and preventive strategies.[67] Use of appropriate urine testing in order to only treat when indicated and tailor broad-spectrum therapy, use of selective antibiotics per guidelines, and use of local antibiograms with inpatient versus outpatient data may be a starting point to reducing antibiotic resistance.

Clostridium difficile Colitis

Hospital-acquired infections such as *C. difficile* colitis contribute nearly $10 billion in excessive expenditures to the US health-care system.[68] Each episode of *C. difficile* colitis confers an increased cost of $11,285 to the hospital admission.[68] Misuse of antibiotics has been associated with bacterial resistance, greater patient morbidity, increased health-care costs, and suppression of normal bacterial flora, leading to *C. difficile* colitis. Antibiotics may be overused after genitourinary surgery, and this overuse is associated with hospital-acquired *C. difficile* infections. The AUA guidelines emphasize that the duration of surgical antimicrobial prophylaxis should only extend throughout the period in which bacterial invasion is likely to establish an infection and that antimicrobial prophylaxis is unnecessary after surgical wound closure. With few exceptions, antimicrobial prophylaxis should not extend beyond 24 hours after the procedure. The specific classes of antibiotics that have been most strongly associated with *C. difficile* colitis include clindamycin, fluoroquinolones, and cephalosporins.[69] Importantly, these are also the classes of antibiotics recommended by the AUA as first- and second-line antibiotic prophylaxis for radical prostatectomy, nephrectomy, and radical cystectomy. Calvert et al. evaluated the incidence of *C. difficile* colitis in genitourinary cancer surgery and found extended antibiotic prophylaxis was associated with higher odds of *C. difficile* infection.[70] C. *difficile* colitis rates have been reported to be as high as 8.8% after radical cystectomy.[71] On multivariate analysis, antibiotic exposure greater than 7 days (odds ratio = 2.2, 95% CI: 1.11–4.44, $p = 0.02$) was independently associated with developing this infection. Efforts are needed to minimize antibiotic exposure and encourage greater compliance with perioperative antimicrobial prophylaxis guidelines.

Special Considerations

PROSTATE BIOPSY

According to the AUA Best Practice Statement, TRUS-guided prostate biopsy (see Chapter 20), performed through a grossly contaminated field, requires important preventative considerations. There is wide variation in the approach to the preparation of the rectum. Some studies found no benefit to either preprocedural povidine-iodine[72] or sodium biphosphate enemas.[73] However, another study found that a bisacodyl suppository rectal preparation the night before or morning of the procedure decreased infectious complications.[74]

The AUA Best Practice Policy Statement on Urologic Surgery Antimicrobial Prophylaxis recommends a fluoroquinolone or first-/second-/third-generation cephalosporin prior to biopsy.[75] Currently, no conclusive data have been found to support either the use of long-course (3 days) over short (1 day) fluoroquinolone regimens, or multiple- versus single-dose schedules.[76] Although antibiotic prophylaxis is effective in preventing infection, leading to a low incidence of sepsis, recently there have been increasing incidences of quinolone-resistant infection resulting from more frequent use of quinolones in the population overall, including at the time of transrectal prostate biopsy.[77] Prebiopsy screening with rectal swabs may allow identification of those men harboring antibiotic-resistant organisms in their endogenous gastrointestinal flora prebiopsy, and for whom fluoroquinolone prophylaxis may not be appropriate.[78] This strategy has revealed a prevalence of about 22% of men harboring fluoroquinolone-resistant bacteria.[78,79] Taylor and colleagues targeted specific antimicrobial prophylaxis based on rectal swab results.[80] These authors were able to show a reduction in post-prostate biopsy infections from 2.6% to 0% ($p = 0.12$) and a cost saving per infectious complication, although this was not statistically significant. However, these methods have not been broadly used and require further prospective investigation.

The need for routine urine culture prior to prostate biopsy is unclear; urine culture appears only to be useful in the decision to refrain from prostate biopsy when bacterial growth is evident.[81] The use of urinalysis or urine dipstick prior to prostate biopsy is widespread; however, there are no published studies to document its benefit.

Most infectious complications after prostate biopsy are limited to symptomatic UTIs and low-grade febrile illness, which can be readily treated with oral or intravenous antibiotics; however, post-biopsy sepsis has emerged as a risk of this procedure. The incidence of infectious complications following prostate biopsy in large multi-institutional studies ranges from 0.1% to 7%, depending upon the antimicrobial prophylactic regimen used,[78,82,83] with approximately 30–50% of these patients having accompanying bacteremia.[72,84] The risk of hospitalization for infectious complications in contemporary studies ranges from 0.6% to 4.1%.[82] The reported incidence of UTI after prostate biopsy typically ranges between 2% and 6%.[85] Bacteremia is frequently accompanied by severe sepsis, which has an overall incidence of 0.1–2.2% following prostate biopsy.[72] One recent study reported that among post–TRUS biopsy patients hospitalized with *E. coli* bacteremia, 25% had severe sepsis requiring intensive care unit admission.[86] In terms of repeat prostate biopsy, Loeb et al. demonstrated a repeat biopsy session was not associated with a greater risk of infectious (OR 0.81, $p = 0.39$) or serious noninfectious urologic complications (OR 0.94, $p = 0.82$) compared to the initial biopsy.[87]

INFLATABLE PENILE PROSTHESES

There are no RCTs regarding the antimicrobial prophylaxis for the insertion of penile prostheses. Data extrapolated from the insertion of mesh during hernia repair and orthopedic implants confirm the benefits of antimicrobial prophylaxis. A significant difference between practice patterns of Sexual Medicine Society of North America member urologists and nonmember urologists in terms of antibiotic irrigation usage, modifications for high-risk patients, and consensus about the importance of antibiotic use with IPP has been observed,[88] even though the AUA guidelines recommend aminoglycoside (or aztreonam*) + first-/second-generation cephalosporin or vancomycin (*aztreonam can be substituted for aminoglycosides in patients with renal insufficiency). Evidence from orthopedic literature suggests that prophylaxis for 24 hours or less is adequate during insertion of penile prosthesis.

Conclusion

Infectious complications from urologic surgery are major sources of postoperative morbidity. Antimicrobial prophylaxis is the periprocedural systemic administration of an antimicrobial agent intended to reduce the risk of post-procedural local and systemic infections. Management of periprocedural infectious complications requires prompt recognition and appropriate intervention. Increasing antibiotic resistance and a lack of new antibiotics in the near future call for a variety of coordinated strategies in an effort of antibiotic stewardship. The appropriate use of antimicrobial prophylaxis in an individual patient requires consideration of not only guidelines but also a comprehensive evaluation of the patient's specific circumstances.

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Chapter 7 Questions

1. AUA guidelines for antibiotic prophylaxis for infective endocarditis during percutaneous nephrolithotomy recommend:
   a. Aminoglycoside
   b. First- or second-generation cephalosporin
   c. Fluoroquinolone
   d. Antibiotic prophylaxis for the prevention of infective endocarditis is not recommended
   e. Clindamycin

2. A 64-year-old female with a history of diabetes mellitus and a hip replacement 1.5 years prior is planned for a right ureteroscopy for a 1-cm mild pole renal calculus. Preoperatively she should receive:
   a. A single dose of quinolone
   b. First- or second-generation cephalosporin
   c. Metronidazole
   d. Clindamycin
   e. TMP-SMX

3. Antibiotic(s) that is/are most commonly associated with *C. difficile* colitis include:
   a. Flagyl and gentamicin
   b. Clindamycin, fluoroquinolones and cephalosporins
   c. Metronidazole and ampicillin/sulbactam
   d. TMP-SMX
   e. Piperacillin/tazobactam

4. A 53-year-old female with quinolone allergy and a history of a prosthetic heart value undergoes left ureteroscopy for a 6-mm midureteral calculus. Preoperatively she should receive:
   a. Aminoglycoside and ampicilin
   b. Clindamycin
   c. Aminoglycoside and first- or second-generation cephalosporin
   d. Flagyl and gentamicin
   e. TMP-SMX

5. A 68-year-old male with a penicillin allergy along with a history of diabetes mellitus and coronary artery disease undergoes placement of an inflatable penile prosthesis. AUA-recommended antimicrobial prophylaxis includes:
   a. Ciprofloxacin and flagyl
   b. Vancomycin
   c. Ampicillin/sulbactam
   d. TMP-SMX
   e. Clindamycin

6. A 62-year-old man presents to the emergency department after outpatient ureteroscopy with a 2-day history of fever, chills, cough, and right-sided pleuritic chest pain. The patient's vital signs are temperature, 101.5°F; heart rate, 120 bpm; respiratory rate, 30 breaths/min; blood pressure, 70/35 mm Hg; and oxygen saturation as measured by pulse oximetry, 80% without oxygen supplementation. A chest radiograph shows a right lower lobe infiltrate. His lactate is 4 mm/L and he requires vasopressin to maintain a MAP ≥65 after appropriate resuscitation. This patient's condition can best be defined as which of the following?
   a. Multi-organ dysfunction syndrome
   b. Sepsis
   c. Septic shock
   d. Severe sepsis
   e. Systemic inflammatory response syndrome

7. What is the first step in the initial management of this patient?
   a. Antibiotic therapy
   b. β-Blocker therapy to control heart rate
   c. Intravenous (IV) fluid resuscitation
   d. Supplemental oxygen and airway management
   e. Vasopressor therapy with dopamine

8. The factor that is independently associated with *C. difficile* colitis after urologic surgery is:
   a. Uncontrolled diabetes mellitus
   b. Immunosuppression
   c. Malignancy
   d. Positive preoperative urine culture
   e. Antibiotic exposure greater than 7 days

9. A 52-year-old female with no growth on a preoperative urine culture undergoes a transvaginal placement of a midurethral sling with inadvertent perforation of the bladder. The surgical wound classification of this procedure is:
   a. Sterile
   b. Clean
   c. Clean contaminated
   d. Contaminated
   e. Dirty-infected

10. A 59-year-old male with cT1c prostate cancer and a penicillin allergy undergoes transperineal prostate focal cryotherapy. Preoperatively, he should receive:
    a. A single dose of quinolone
    b. First- or second-generation cephalosporin
    c. Metronidazole
    d. Clindamycin
    e. TMP-SMX

Answers

1. **d.** AUA guidelines do not recommend antibiotics for prevention of infective endocarditis.
2. **a.** A hip replacement within 2 years and diabetes places the patient at risk for hematogenous spread of infection; AUA guidelines recommend a single dose of quinolone.
3. **b.** Clindamycin, fluoroquinlones, and cephalosporins place the urologic patient at greatest risk for *C. difficile* colitis.
4. **c.** AUA guidelines recommend aminoglycoside and first- or second-generation cephalosporin for antibiotic prophylaxis involving an implanted prosthesis.
5. **b.** AUA guidelines recommend vancomycin in penicillin -allergic patients for antibiotic prophylaxis involving an implanted prosthesis.

6. **c.** The definition of septic shock is sepsis and vasopressor therapy needed to elevate MAP (mean arterial pressure) ≥65 mm Hg and lactate >2 mmol/L (18 mg/dL) despite adequate fluid resuscitation.
7. **d.** Respiratory stabilization is the first step in management.
8. **e.** Prolonged antibiotic use >7 days have been associated with C. *difficile* colitis (odds ratio 2.2).
9. **c.** The definition of a clean contained procedure is an operative wound that enters the respiratory, GI, genital, or urinary tract under controlled conditions without unusual contamination when no infection or major break in technique has occurred.
10. **d.** AUA guidelines recommend clindamycin in those with a penicillin allergy undergoing surgery not involving the urinary tract or bowel (Case Table 7.1).

Case Table 7.1 Recommended Antimicrobial Prophylaxis for Urologic Procedures

Procedure	Organisms	Prophylaxis Indicated	Antimicrobial(s) of Choice	Alternative Antimicrobial(s)	Duration of Therapy*
Lower Tract Instrumentation					
Removal of external urinary catheter	GU tract†	If risk factors‡,§	■ Fluoroquinolone¶ ■ TMP-SMX¶	■ Aminoglycoside (aztreonam¥) ± ampicillin¶ ■ 1st-/2nd-gen. cephalosporin¶ ■ Amoxicillin/clavulanate¶	=24 hours¶
Cystography, urodynamic study, or simple cystourethroscopy	GU tract	If risk factors§	■ Fluoroquinolone ■ TMP-SMX	■ Aminoglycoside (aztreonam¥) ± ampicillin ■ 1st-/2nd-gen. cephalosporin ■ Amoxicillin/clavulanate	=24 hours
Cystourethroscopy with manipulation|	GU tract	All	■ Fluoroquinolone ■ TMP-SMX	■ Aminoglycoside (aztreonam¥) ± ampicillin ■ 1st-/2nd-gen. cephalosporin ■ Amoxicillin/clavulanate	=24 hours
Prostate brachytherapy or cryotherapy	Skin	Uncertain	■ 1st-gen. cephalosporin	■ Clindamycin**	=24 hours
Transrectal prostate biopsy	Intestine††	All	■ Fluoroquinolone ■ 1st-/2nd-/3rd-gen. cephalosporin	■ TMP-SMX ■ Aminoglycoside (aztreonam¥)	=24 hours
Upper Tract Instrumentation					
Shock-wave lithotripsy	GU tract	If risk factors	■ Fluoroquinolone ■ TMP-SMX	■ Aminoglycoside (aztreonam¥) ± ampicillin ■ 1st-/2nd-gen. cephalosporin ■ Amoxicillin/clavulanate	=24 hours
Percutaneous renal surgery	GU tract and skin‡‡	All	■ 1st-/2nd-gen. cephalosporin ■ Aminoglycoside (aztreonam¥) + metronidazole or clindamycin	■ Ampicillin/sulbactam ■ Fluoroquinolone	=24 hours
Ureteroscopy	GU tract	All	■ Fluoroquinolone ■ TMP-SMX	■ Aminoglycoside (aztreonam¥) ± ampicillin ■ 1st-/2nd-gen. cephalosporin ■ Amoxicillin/clavulanate	=24 hours
Open or Laparoscopic Surgery					
Vaginal surgery (includes urethral sling procedures)	GU tract, skin and Grp B *Strep.*	All	■ 1st-/2nd-gen. cephalosporin ■ Aminoglycoside (aztreonam¥) + metronidazole or clindamycin	■ Ampicillin/sulbactam ■ Fluoroquinolone	=24 hours
Without entering urinary tract	Skin	If risk factors	■ 1st-gen. cephalosporin	■ Clindamycin	Single dose
Involving entry into urinary tract	GU tract and skin	All	■ 1st-/2nd-gen. cephalosporin ■ Aminoglycoside (aztreonam¥) + metronidazole or clindamycin	■ Ampicillin/sulbactam ■ Fluoroquinolone	=24 hours
Involving intestine§§	GU tract, skin and intestine	All	■ 2nd/3rd gen. cephalosporin ■ Aminoglycoside (aztreonam¥) + metronidazole or clindamycin	■ Ampicillin/sulbactam ■ Ticarcillin/clavulanate ■ Piperacillin/tazobactam ■ Fluoroquinolone	=24 hours
Involving implanted prosthesis	GU tract and skin	All	■ Aminoglycoside (aztreonam¥) + 1st/2nd gen. cephalosporin or vancomycin	■ Ampicillin/sulbactam ■ Ticarcillin/clavulanate ■ Piperacillin/tazobactam	=24 hours

*Additional antimicrobial therapy may be recommended at the time of removal of an externalized urinary catheter.
†GU tract: Common urinary tract organisms are *E. coli, Proteus sp., Klebsiella sp., Enterococcus.*
‡See Table 1 "Patient-related factors affecting host response to surgical infections."
§If urine culture shows no growth prior to the procedure, antimicrobial prophylaxis is not necessary.
¶Or full course of culture-directed antimicrobials for documented infection (which is treatment, not prophylaxis).
¥Aztreonam can be substituted for aminoglycosides in patients with renal insufficiency.
|Includes transurethral resection of bladder tumor and prostate, and any biopsy, resection, fulguration, foreign body removal, urethral dilation or urethrotomy, or ureteral instrumentation including catheterization or stent placement/removal.
**Clindamycin, or aminoglycoside + metronidazole or clindamycin, are general alternatives to penicillins and cephalosporins in patients with penicillin allergy, even when not specifically listed.
††Intestine: Common intestinal organisms are *E. coli, Klebsiella sp., Enterobacter, Serratia sp, Proteus sp., Enterococcus*, and anaerobes.
‡‡Skin: Common skin organisms are *S. aureus*, coagulase negative *Staph. sp.*, Group A *Strep. sp.*
§§For surgery involving the colon, bowel preparation with oral neomycin plus either erythromycin base or metronidazole can be added to or substituted for systemic agents.
Key: gen, generation; GU, genitourinary; TMP-SMX, trimethoprim-sulfamethoxazole.
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8 Classification of Complications and Assessment of Quality of Care

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CHAPTER OUTLINE

Introduction
Definition of Complications
Common Terminology Criteria for Adverse Events
Clavien-Dindo System
The International Continence Society and the International Urogynecological Association Classification of Complications Related Directly to the Insertion of Grafts and Prosthetics
National Quality Registries
Quality Improvement Strategies
Plan-Do-Study-Act Cycle
Statistical Process Control
Root Cause Analysis
Lean Production System
Failure Mode and Effects Analysis
Summary
Chapter 8 Questions and Answers

KEY POINTS

1. A surgical complication is any event that deviates from the normal or expected course of action either during or after surgery.
2. The Common Terminology Criteria for Adverse Events system is a comprehensive set of criteria for the standardized classification of complications after cancer therapy and has been broadly accepted and extensively used by cooperative research and industry groups.
3. The Clavien-Dindo classification system is centered around the risk and invasiveness of the therapy required to resolve the complication.
4. The International Continence Society and the International Urogynecological Association classification system is extraordinarily complex and incorporates site, timing, and category of complications into six- or seven-digit code (with three numbers and three to four letters) to cover any conceivable complication after graft or prosthetic placement.
5. Despite the lack of unanimity in how surgical complications should be classified, significant strides have been made in national outcome registries such as the National Surgical Quality Improvement Program and the American Urological Association Quality registry.
6. Plan-Do-Study-Act, also known as rapid cycle improvement, is an iterative, four-stage, problem-solving model aimed at making positive changes in health-care processes.
7. Statistical process control is a set of methods for assessing ongoing quality improvement measures in real time and relies on the early identification of special cause variation. Alternatively, a process that displays only common cause variation may be stable and predictable and yet still unacceptable.
8. Root cause analysis is a formalized investigation and problem-solving method focused on identifying and understanding the underlying cause of an untoward event.
9. Lean methodologies – used in the manufacturing of Toyota cars – aims to improve processes by removing activities that are nonvalue-added through retrospective investigations of errors that interrupt the sequence of efficient operations.
10. Failure mode effects analysis aims to prevent errors through proactive risk assessment – that is, to prevent errors by identifying all the ways a process could fail, estimating the predicted probabilities and consequence of failures, and then taking action to prevent the potential failures from occurring.
11. The key factors necessary for success in quality improvement are strong and committed senior leadership, buy-in from rank-and-file members of the organization, and open lines of communication between leadership and involved stakeholders.

Introduction

Since the publication of *Crossing the Quality Chasm*,[1] there has been a renewed interest in improving outcomes after surgery in the United States. However, it remains unclear what constitutes a "bad" outcome after surgery as some complications are inherent to the procedure and expected to occur. Despite this uncertainty, the rate of surgical complications remains one of the most commonly used surrogate measures of surgical quality. In an effort to guide the systematic measurement and reporting of surgical complications for quality improvement purposes, several different classification systems for surgical complications have been developed despite none having emerged with universal acceptance. In this chapter, we provide a contextual framework for understanding how surgical complications are classified and how these reporting systems can be leveraged for quality improvement. Specifically, our objective is to review the available reporting systems used for complications after urologic surgery, to highlight deficiencies in these reporting systems, and to review how these classifications systems can be conceptualized within the framework of one or more prevailing quality improvement paradigms.

Definition of Complications

Before a classification system for surgical complications can be adopted, a standardized definition of what exactly constitutes a surgical complication is needed. In broad terms, a surgical complication is any event that deviates from the normal or expected course of action either during or after surgery. While many patient-, provider-, and system-level factors contribute to variations in surgical complications, a standardized reporting system is the sine qua non of effective surgical quality–improvement initiatives. There are several different proposed classification systems for reporting and classifying surgical complications, and these are summarized below.

COMMON TERMINOLOGY CRITERIA FOR ADVERSE EVENTS

The Common Terminology Criteria for Adverse Events (CTCAE) system is a comprehensive set of criteria for the standardized classification of complications after cancer therapy and has been broadly accepted and extensively used by cooperative research and industry groups since its introduction in the early 1980s.[2,3] Now in its fourth version, the CTCAE system uses a range of grades from 1 to 5 to classify surgical complications, ranging from mild complications to death (Table 8.1). In general, one advantage to the CTCAE system is that it is a relatively simple classification system, at least with respect to surgical complications. While this makes it ideally suited for NCI-sponsored trials where the focus is on unexpectedly serious and/or life-threatening surgical complications, it does not have the granularity needed to be used for comparative effectiveness research or quality improvement.

Table 8.1 CTCAE System for the Classification of Surgical and Medical Procedures

1	Asymptomatic or mild symptoms; clinical or diagnostic observations only; intervention not required
2	Moderate; minimal, local, or noninvasive intervention indicated; limiting age-appropriate instrumental activities of daily living (ADL)
3	Severe or medically significant but not immediately life threatening; hospitalization or prolongation of existing hospitalization indicated; disabling; limiting self-care ADL
4	Life-threatening consequences; urgent intervention indicated
5	Death

Table 8.2 Clavien-Dindo Classification of Complications

Grade	Definition
Grade I	Any deviation from the normal course without the need for pharmacological treatment or surgical, endoscopic and radiologic interventions. Allowed therapeutic regimens are: drugs as antiemetics, antipyretics, analgesics, diuretics and electrolytes, and physiotherapy. This grade also includes wound infections opened at the bedside. Example: wound infection, postoperative ileus not requiring total parenteral nutrition (TPN)
Grade II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications. Example: blood transfusion, urinary tract infection, ileus requiring TPN
Grade III	Requiring surgical, endoscopic or radiological intervention. Grade IIIa complications do not require anesthesia. Grade IIIb complications require anesthesia Example: take back to the OR for any reason, stent placement for ureteral injury
Grade IV	Life-threatening complication (including CNS complications)* requiring IC/ICU management. Grade IVa is single organ dysfunction. Grade IVb is multi-organ dysfunction. Example: sepsis, stroke, cardiopulmonary event
Grade V	Death of a patient. If the patient suffers from a complication at the time of discharge, the suffix "d" (for "disability") is added to the respective grade of complication. This label indicates the need for a follow-up to fully evaluate the complication

*brain hemorrhage, ischemic stroke, subarachnoidal bleeding, but excluding transient ischemic attacks (TIA)

IC: intermediate care; ICU: intensive care unit

(With permission from Dindo D, Demartines N, Clavien PA. The Clavien-Dindo Classification of Surgical Complications. Ann Surg. 2004; 244: 931–937.)

CLAVIEN-DINDO SYSTEM

In an attempt to standardize surgical outcome reporting with increased precision, Clavien et al. published a grading system for the severity of surgical complications. This new system, published in 1992, was centered on the risk and invasiveness of the therapy required to resolve the complication (Table 8.2).[4] In theory, this minimizes the influence of subjective interpretation on complication scoring because it is rooted in objective outcomes. Initially, four grades of complications were described; however, in 2004,

Dindo et al. introduced a modification to the Clavien classification system using five grades contained within seven levels.[5] This revision added further precision by characterizing whether an intervention required general anesthesia or whether a complication led to organ failure and/or admission to an intensive care unit. This reporting system, known as the Clavien-Dindo classification system, has been extensively validated and evaluated for interobserver variability.[6]

While this classification method has increased in popularity in recent years, it is not without its limitations. First, many of these complications remain susceptible to subjective interpretation, which may create variability within the grading assignments. For example, urologists may grade a recognized rectal injury during a radical prostatectomy differently: grade I for prolonged hospital stay versus grade III for intraoperative repair under general anesthesia.[7] Second, some interventions may be performed under local anesthesia at one institution but general anesthesia at another, which introduces inter-rater variability within grades III and IV.[8] Third, this system may not capture patients who have multiple complications within the same grade. Last two patients with the same complication may be managed differently at two separate institutions (e.g., IVC filter versus heparinization alone for DVT). Because of these challenges, the utility of the Clavien-Dindo classification system for national quality-improvement initiatives has been limited.

THE INTERNATIONAL CONTINENCE SOCIETY AND THE INTERNATIONAL UROGYNECOLOGICAL ASSOCIATION CLASSIFICATION OF COMPLICATIONS RELATED DIRECTLY TO THE INSERTION OF GRAFTS AND PROSTHETICS

In an effort to clarify terminology and to promote a registry for the improvement of pelvic-floor surgical procedures, the International Continence Society (ICS) and International Urogynecological Association (IUGA) have established a joint working group for classifying complications related to the insertion of prosthetics and grafts for female pelvic floor surgery.[9] The article recommends precise definitions for specific complications by distinguishing among local systemic complications. Novel terms such as *exposure, compromise, perforation, extrusion, separation, contraction,* and *prominence* are described in this report. The classification system itself is extraordinarily complex and incorporates anatomic site, timing, and category of complication into a six- or seven-digit code (with three numbers and three to four letters) to cover any conceivable complication after graft or prosthetic placement. By way of example, the code 1AaT1S1 would indicate asymptomatic vaginal prominence with no epithelial separation in the area of the suture line within 48 hours of surgery. While the complexity of this system may limit its use in daily practice, this system may be useful for comparative effectiveness research or surgical registries. A user-friendly calculator can be found online at the ICS website.[10]

NATIONAL QUALITY REGISTRIES

Despite the lack of unanimity in how surgical complications should be classified, significant strides have been made in national outcome–based surgical-quality assessment. The National Surgical Quality Improvement Program (NSQIP), for example, has been measuring outcomes for many types of surgeries and, for a small subset of institutions, publically reporting them.[11] Originally established in 1994, the goal of NSQIP was to prospectively collect surgical outcome data at Veterans Affairs (VA) hospitals and compare observed outcomes to risk-adjusted, model-based predictions. In 1999, it began expanding to include private hospitals to test the feasibility of implementing the system outside the VA. However, participation in NSQIP has not necessarily resulted in improved outcomes compared with nonparticipating hospitals. While initially showing promise for the VA system, recent data have challenged the association between hospital participation in NSQIP and improvement in outcome measures over time.[12] Furthermore, many important patient-centered outcomes are not captured by NSQIP such as margin status, return to work, and survival beyond 90 days.

With the aim of improving quality of care for urologic patients, the American Urological Association (AUA) established the AUA Quality registry (AQUA) in the summer of 2014. The AQUA registry is a national urologic disease registry designed to measure and report quality and patient-centered outcomes after urologic surgery. Using data directly extracted from commercially available electronic medical records, AQUA aggregates and organizes clinical and patient-reported data on diagnostic and therapeutic interventions, outcomes, and resource utilization.[13] While still in its infancy, data generated from AQUA will be used to support evidence-based decision support mechanisms and will provide feedback to urologists regarding their individual and/or practice-level performance on a range of quality measures benchmarked against their peers at the national and regional levels.

Quality Improvement Strategies

With an understanding of the basic principles of performance measurement and quality improvement, the next question is how to actually improve the quality of care. Unfortunately, the answer is often not simple. The overall goals of measuring health care are to ascertain whether the delivery of health care results in desired outcomes and to determine the degree to which health care adheres to processes that are rooted in scientific evidence, professional consensus, and patient preference. The theoretical framework that underlies successful quality-improvement programs emphasizes strategic vision, an understanding of organizational culture, streamlined data management, and infrastructure for efficient dissemination of results.[14] As such, it is important to understand many different process-improvement techniques that can identify inefficiencies, ineffective care, and preventable errors that arise from system or process failures.[15] The remaining portion of this chapter will focus on strategies and tools for quality improvement, including failure modes and effects analysis, plan-do-study-act (PDSA), statistical process control, Lean methodologies, and root cause analysis.

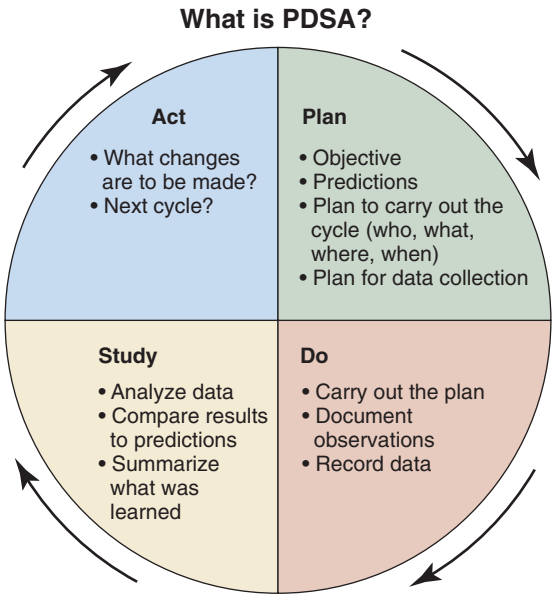


Figure 8.1 What is PDSA?

PLAN-DO-STUDY-ACT CYCLE

PDSA, also known as rapid cycle improvement, is an iterative, four-stage problem-solving model aimed at making positive changes in health-care processes (Fig. 8.1). This approach has been widely used by the Institute for Healthcare Improvement.[16,17] This strategy invokes a cyclic approach to assessing the impact of successive changes in the process.[18,19] The basic structure of PDSA is:

1. Plan. Assemble a team that has knowledge of the problem, describe the problem, and identify and analyze causes.
2. Do. Implement the action plan in a trial or small test group, collecting data prospectively.
3. Study. Analyze the data collected, and assess whether the new process has a level of performance and/or random variation that is superior to that displayed by the old process.
4. Act. If deemed successful, standardize the improvement and begin to use it regularly. If not successful, either modify it and test it again or discard it.

There are good examples of large-scale quality–improvement efforts using the PDSA approach in urology. The Michigan Urological Surgery Improvement Collaborative (MUSIC) is a physician-led group collaboration that aims to improve quality related to prostate cancer care in Michigan through consortium-wide provider and practice feedback on performance.[20] While this physician-led innovative regional collaborative has demonstrated promising results,[21–23] its reproducibility in markets without the financial support of the dominant insurer, the collegial interplay between community and academic urologists, and the committed time and support of clinical thought leaders is yet to be determined.

STATISTICAL PROCESS CONTROL

Statistical process control (SPC) is a set of methods used in the assessment of ongoing quality-improvement measures in real time. Originally developed by Walter A. Shewart in the early 20th century to help AT&T make better telephones, SPC methods have also been used in a wide variety of quality-improvement efforts including munitions manufacturing in World War II, software engineering, and health care.[24–26] Shewart hypothesized that the best way to improve a process was to identify and reduce variation and, when possible, to move the entire process in the preferred direction. In so doing, he distinguished between two general types of variations: special cause variation and common cause variation.

Common cause variation is variation that is inherent to the process itself (i.e., noise *within* the system) and is predictable and stable. Special cause variation arises from data that vary in an unpredictable way and signal a change in the process. Neither type of variation is desirable or undesirable in and of itself. When a process incurs an unanticipated special cause, it's usually undesirable (e.g., higher rate of retained sponges in the current year compared to previous years). However, a special cause may be desirable if improvements are made to the process and the special cause signals a change in the desired direction (e.g., lower rate of retained sponges after implementation of policy that mandates correct instrument counts prior to fascial closure). Alternatively, a process that displays only common cause variation may be stable and predictable and yet still altogether unacceptable. Turnover time between surgical cases, for example, may be stable and predictable at 2 hours plus or minus 5 minutes, but most hospitals (and surgeons!) would consider this amount of time unacceptable.

Because quality-improvement strategies rely on understanding the type of variation exhibited by a process, methods to correctly identify types of variations are imperative. To assist researchers in differentiating common cause from special cause variation, Shewart developed a tool called the *control* chart. The basic elements of a control chart are exhibited in Fig. 8.2. The sample data describe the number of surgical readmissions a large busy hospital experienced on a monthly basis over the past 2 years. Several features of this chart are important to recognize. First, the control chart is a real-time, ongoing record of an event over time (X-axis). Second, the performance characteristic being measured is plotted on the Y-axis. Third, control charts have a measure of central tendency called the centerline (usually the mean). Fourth, upper and lower control limits allow interested parties to quantitatively identify special causes that reveal instability in the process. Last green observations represent common cause variation while red observations indicate special cause variation. While it is beyond the scope of this chapter to go into great detail regarding chart types, an excellent source of additional information in this regard is *Improving Healthcare with Control Charts*.[26]

Several limitations of SPC methods should be acknowledged. First, control charts assume that each event under consideration is separate and independent of the preceding and succeeding events and also that each event has a constant or equal probability of occurring.[27] Because one is rarely able to prove or disprove this assumption, most tend to ignore it.[27] Second, control charts also have a potential issue with skewness. If the subgroup size for the event under examination is too small, then it will be difficult to discern special causes accurately. Stated differently, the

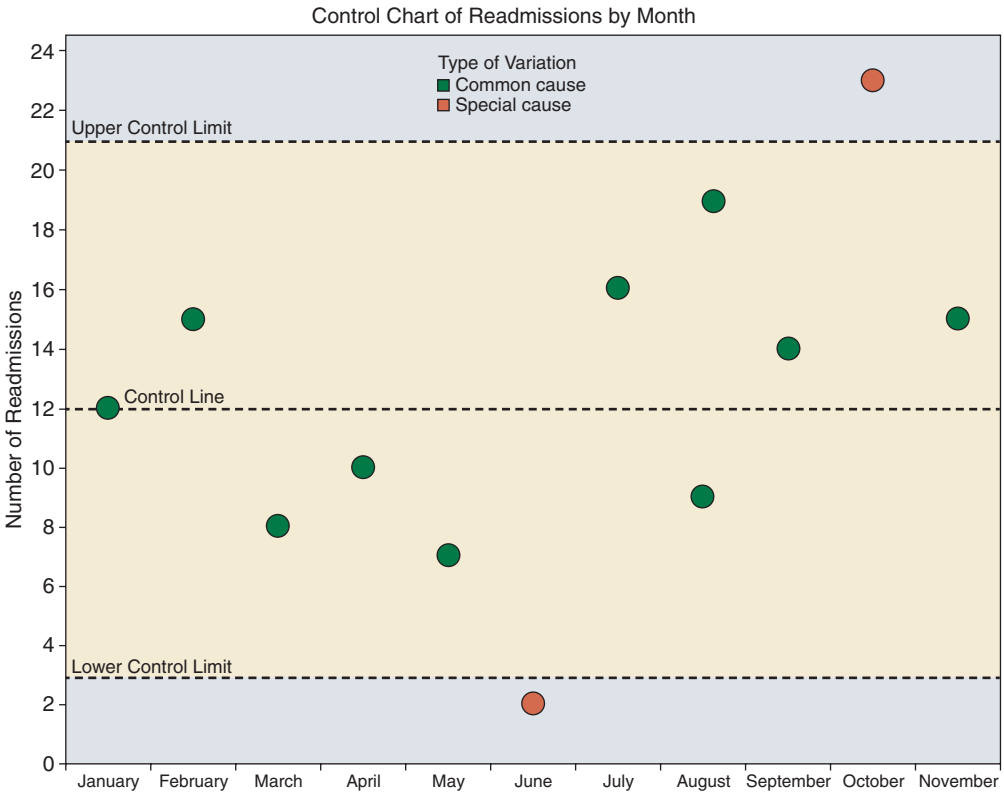


Figure 8.2 Control chart of readmissions by month.

smaller the subgroup size, the less sensitive the control chart. As a result, most SPC experts recommend at least 20–25 observations before control limits are calculated.[26]

ROOT CAUSE ANALYSIS

Root cause analysis (RCA) is a formalized investigation and problem-solving method focused on identifying and understanding the underlying cause of an untoward event. Used extensively in engineering,[28] RCA is now a requirement by The Joint Commission for all sentinel events.[29] Operating on the assumption that the system, rather than the individual, is the most likely root cause of most problems, RCA is a technique used to identify trends and assess risk whenever an error is suspected.[30] Because the analysis begins after an event, RCA procedures are reactive in nature, retrospectively outlining the sequence of events leading to that event, charting possible causative factors, and identifying root causes to completely vet the origins of the event in question.[31] Given that the process is labor-intensive, typically a multidisciplinary quality team will corroborate the principal findings of the RCA to increase the validity of the findings (Fig. 8.3).[32]

The last phase of the RCA analysis is developing recommendations for system-wide process improvement, based on the pertinent findings from the investigation. The significance of this final stage is underscored by a review of the literature on RCA, where the authors conclude that there is little evidence to substantiate the claim that RCA can improve patient safety by itself.[33] To improve the generalizability of the findings from the RCA, some groups have moved to performing several RCA processes simultaneously

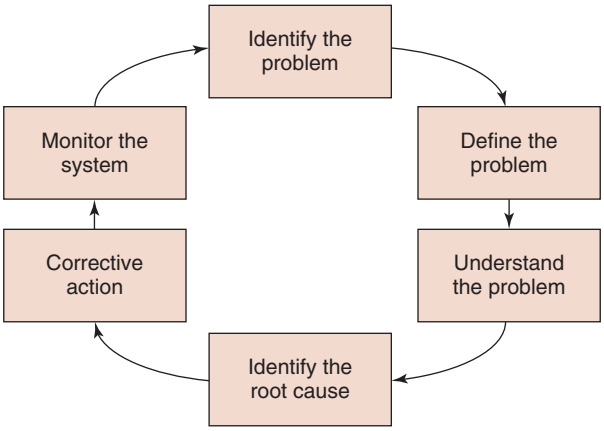


Figure 8.3 Root cause analysis flowchart.

to examine multiple cases within a single review for certain categories of events.[34–36] Due to the myriad types of adverse events, special consideration is required to differentiate system from process factors. Furthermore, most experts in RCA will reiterate that it is imperative to avoid assigning individual blame. A commonly held notion is that it is truly rare for errors to be associated with provider neglect or malfeasance.[37] The majority of individual factors can been addressed through system-wide education, training, and installing fail-safes that make errors difficult to commit.

LEAN PRODUCTION SYSTEM

Lean methodologies – used in the manufacturing of Toyota cars – overlaps with SPC and RCA methods in that this

approach aims to improve processes by removing activities that are nonvalue-added (also known as waste) through retrospective investigations of errors that interrupt the sequence of efficient operations.[38–41] In this way, quality improvement efforts not only look at effectiveness but also costs and in essence determine the value of each step in the process. Using these principles, health-care stakeholders have evaluated nonvalue-added processes in the operations of pathology labs,[42–45] pharmacies,[46–49] and blood banks[50,51] – similar to the Toyota Production System. These methods rely on accurately defining the problem, using RCA analysis to investigate the problem, setting goals to address the problem, and clarifying who is responsible for removing ambiguity and implementing workarounds. In health care, analogous measures are taken to ensure the right patient gets the right service (output), who delivers the service (responsibility), when the service is delivered (connection), and precisely how the service is delivered.[52]

FAILURE MODE AND EFFECTS ANALYSIS

All the previous quality-improvement measures up to this point have focused on reactionary planning to events that have already occurred, even if the techniques employ prospective analysis of changes to the system. In 2001, however, The Joint Commission began requiring proactive risk management activities in an effort identify and predict system weaknesses so that patient harm could be prevented as opposed to being studied in retrospect.[53] While failure mode and effects analysis (FMEA) techniques had been used in health care for decades, this mandate generated renewed interest in the field of proactive risk assessment using FMEA. FMEA techniques were initially used by engineers in the mid-20th century to evaluate failures in military, automotive, and aeronautic and space industries.[54,55] FMEA is an inductive reasoning (forward logic) single point of failure analysis that identifies potential problems based on experience with similar products and processes.[56,57] Failure indicates a loss of function whereas failure mode indicates the specific manner in which the function was lost. Effects analysis refers to downstream consequences of failure on different levels within the system. The goal of FMEA is to prevent errors through proactive risk assessment – that is, to prevent errors by identifying all the ways a process could fail, estimating the predicted probabilities and consequences of failures, and then taking action to prevent the potential failures from occurring.[58,59] In health care, this method focuses on the system of care and uses multidisciplinary teams to assess processes from quality-improvement perspectives.[60] FMEA methods have been used to prevent chemotherapy errors,[61] PCA oversedation,[62] misadministration of IV contrast in outpatients,[63] and blood transfusion errors in pediatric emergencies.[64]

Summary

In this chapter, we have reviewed the dominant methods for classifying complications, which should equip the urologic surgeon not only to be able to effectively recognize areas that need improvement but also to begin to formulate strategies that promote effective disease management throughout all levels of the health-care organization. We have also provided the reader with a comprehensive review of how quality improvement is approached from a practical standpoint. This understanding will undoubtedly assist the next generation of urologic surgeons in navigating the emerging quality and value-based health-care environment.

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Chapter 8 Questions

1. A patient undergoes a holmium laser enucleation of the prostate for a 250-g prostate. His intraoperative course was notable for prolonged and difficult tissue morcellation. Postoperatively, he was noted to have massive abdominal distention, pain, and minimal urine output. A cystogram reveals an intraperitoneal bladder perforation. He undergoes emergent repair of the bladder perforation. He does not require ICU care and he remained hemodynamically stable throughout. According to the Clavien-Dindo classification system, what grade of complication does this constitute?
   a. Grade I
   b. Grade II
   c. Grade III
   d. Grade IV
   e. Grade V

2. A patient develops nausea after a cystectomy necessitating the administration of Zofran for relief. According the Clavien-Dindo classification system, what grade of complication is this?
   a. Not a complication
   b. Grade I
   c. Grade IIa
   d. Grade IIb
   e. Grade III

3. A patient requires a blood transfusion after a cystectomy. According to the Clavien-Dindo classification system, what grade complication is this?
   a. Grade I
   b. Grade II
   c. Grade IIIa
   d. Grade IIIb
   e. Grade IV

4. A patient requires total parenteral nutrition for a prolonged ileus after a cystectomy. According to the Clavien-Dindo classification system, what grade complication is this?
   a. Grade I
   b. Grade II
   c. Grade IIIa
   d. Grade IIIb
   e. This is not a complication according to the Clavien-Dindo classification system

5. What are the types of variations in statistical process control?
   a. Common cause variation
   b. Special cause variation
   c. Both A and B
   d. Neither A or B
   e. Stochastic variation

6. In the context of statistical process control, special cause variation:
   a. Is always undesirable
   b. May be desirable if improvements are made to the process and the special cause signals a change in the desired direction
   c. Arises from data that signal a change in the process
   d. Both b and c
   e. None of the above

7. Which of the following are limitations to the statistical process control methods?
   a. Control charts assume that each event under consideration is separate and independent of the preceding and succeeding events
   b. Each event on the control chart has a constant or equal probability of occurring
   c. If the subgroup size for the event under examination is too small, then it will be difficult to discern special causes accurately
   d. All of the above
   e. None of the above

8. Limitations of the Clavien-Dindo classification include:
   a. Complications may be susceptible to subjective interpretation
   b. Some interventions may be performed under local anesthesia at one institution but general anesthesia at another
   c. May not capture patients who have multiple complications within the same grade
   d. All of the above
   e. None of the above

9. Which of these quality improvement measures uses proactive risk assessment?
   a. Plan-Do-Study-Act
   b. Statistical process control
   c. Failure mode and effects analysis
   d. Root cause analysis
   e. None of the above

10. Which is true regarding root cause analysis?
    a. It operates on the assumption that an individual, not the system, is the most likely root cause
    b. The analysis begins after the event
    c. The majority of individual factors cannot be addressed through system-wide education, training, and installing fail-safes that make errors difficult to commit
    d. All of the above
    e. None of the above

Answers

1. **c.** Because the patient required a surgical intervention under anesthesia, this is a grade IIIb complication.
2. **b.** This is a grade I complication because the patient required an antiemetic.
3. **a.** Because the patient received a pharmacologic intervention other than what was allowed for a grade I complication, this constitutes a grade II complication.
4. **b.** Total parenteral nutrition is a pharmacologic intervention that falls under the grade II designation.
5. **c.** Both common cause and special cause variation are types of variations within the statistical process control framework.
6. **d.** Special cause variation in and of itself is neither undesirable nor desirable. If the special cause variation

signals a change in the desired direction after an intervention, then this is clearly special cause variation that is desirable. An example of this would be a lower retained sponge rate after implementing a policy that states every patient must have a correct instrument count before fascial closure.

7. **d.** First, control charts assume that each event under consideration is separate and independent of the preceding and succeeding events and also that each event has a constant or equal probability of occurring. Because one is rarely able to prove or disprove this assumption, most tend to ignore it. Second, control charts also have a potential issue with skewness. If the subgroup size for the event under examination is too small, then it will be difficult to discern special causes accurately. Stated differently, the smaller the subgroup size, the less sensitive the control chart. As a result, most SPC experts recommend at least 20–25 observations before control limits are calculated.
8. **d.** Despite improvements to the classification system meant to reduce subjectivity within grade designations, some complications may be susceptible to variation in interpretation. Furthermore, some interventions may be performed under anesthesia at one institution but not under anesthesia at another.
9. **c.** Failure mode and effects analysis is an inductive reasoning (forward logic) single point of failure analysis that identifies potential problems based on experience with similar products and processes. The other quality improvement paradigms focus on reactionary planning to events that have already occurred, even if the techniques employ prospective analysis of changes to the system.
10. **b.** Operating on the assumption that the system, rather than the individual, is the most likely root cause of most problems, RCA is a technique used to identify trends and assess risk whenever an error is suspected. Because the analysis begins after an event, RCA procedures are reactive in nature, retrospectively outlining the sequence of events leading to that event, charting possible causative factors, and identifying root causes to completely vet the origins of the event in question.

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SECTION II

Common Surgical Considerations

9 Complications of the Incision and Patient Positioning

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CHAPTER OUTLINE

Seroma
Pathogenesis and Clinical Features
Prevention and Management
Hematomoa
Pathogenesis and Clinical Features
Prevention and Management
Surgical Site Infection
Definition
Risk Stratification
Microbiology
Prevention
Preoperative and Intraoperative Techniques
Antimicrobial Prophylaxis
Diagnosis and Management
Wound Dehiscence
Pathogenesis and Clinical Features
Suture Selection and Technique
Layered Versus Mass Closure
Nerve/Plexus Injuries
Upper Extremity Nerve Injuries
Lower Extremity Nerve Injuries
Injuries to the Femoral Nerve
Injuries Resulting From Lithotomy Position
Injuries Related to Positioning for Robotic Surgery
Chapter 9 Questions and Answers

KEY POINTS

1. Large hematomas that collect in the retroperitoneum or rectus sheath may cause paralytic ileus, anemia, and ongoing bleeding resulting from the consumption of coagulation factors.
2. Wounds that involve large skin flaps or those with large potential spaces in which blood could collect should be drained with a closed-suction surgical drain until the output of these drains decreases.
3. Intraoperative strategies to prevent wound infection include aseptic technique to reduce the microbial inoculum as well as good surgical practice to minimize dead space and devitalized tissue.
4. Antibiotic prophylaxis is recommended for all class II (clean-contaminated) wounds and for class I_D (clean) wounds in which prosthetic material or a vascular graft is implanted because the consequences of infection are serious in these instances.
5. Severe infections, such as necrotizing fasciitis, represent surgical emergencies, and patients should be taken immediately back to the operating room for wide debridement.
6. The use of vacuum-assisted closure should be limited when wounds are near conduits, anastomoses, and neobladders because this technique may be associated with an increased rate of cutaneous fistula formation.
7. If clinical suspicion of dehiscence remains despite equivocal physical examination findings, imaging studies such as ultrasound or computed tomography can be used.
8. Investigators have demonstrated that wounds that have been closed with a suture length that is twice as long as the wound have a higher rate of wound dehiscence than do wounds closed with suture that is four times the length of the wound.
9. Although brachial plexus injuries have been reported to result from excessive extension and external rotation during surgical procedures in the supine position, including radical prostatectomy, most brachial plexus injuries occur during procedures in the flank position, which is commonly used for procedures involving the kidney and retroperitoneum.
10. Retractor injuries to the femoral nerve occur when the blades of the retractor are placed directly on the psoas muscle, where they may compress the nerve directly or indirectly by trapping the nerve against the lateral pelvic wall.
11. Robotic-assisted surgery may be associated with increased risk of positioning injuries, including both traditional neuromuscular injuries to the upper and lower extremities as well as less common injuries such as vision loss, rhabdomyolysis, and compartment syndrome.

Successful surgical therapy depends on proper healing of the surgical wound. Problems with wound healing can lead to seromas, hematomas, surgical site infections (SSIs), dehiscence, and incisional hernias. In addition, nerve injuries related to patient positioning or retractor placement may affect postoperative mobility. All these complications increase morbidity and can contribute to mortality in surgical patients.

Complications related to the incision and patient positioning are important for all surgeons to be aware of because they are among the most common complications following operative procedures. Often, these complications are relatively minor and may resolve with conservative management (e.g., simple wound seromas or hematomas). However, at times their resolution may be expensive and time-consuming (e.g., complicated wound infection), may require additional surgical procedures (e.g., incisional hernia), or may cause permanent disability (e.g., postoperative neurapraxia). Therefore management of these complications is focused on prevention, as well as prompt recognition and appropriate treatment. The objective of this chapter is to review common complications of the incision and patient positioning with respect to their pathogenesis, clinical features, prevention, and management.

Seroma

PATHOGENESIS AND CLINICAL FEATURES

One of the most common and likely underreported complications following operative procedures is the development of a wound seroma (Fig. 9.1A). Although typically a benign finding, when not treated, seromas may lead to more serious wound infections, wound breakdown, or potentially skin necrosis. A *seroma* is a collection of sterile, clear, ultrafiltrated serum, lymphatic fluid, or liquified fat.[1] The fluid is usually clear, amber, and slightly viscous.

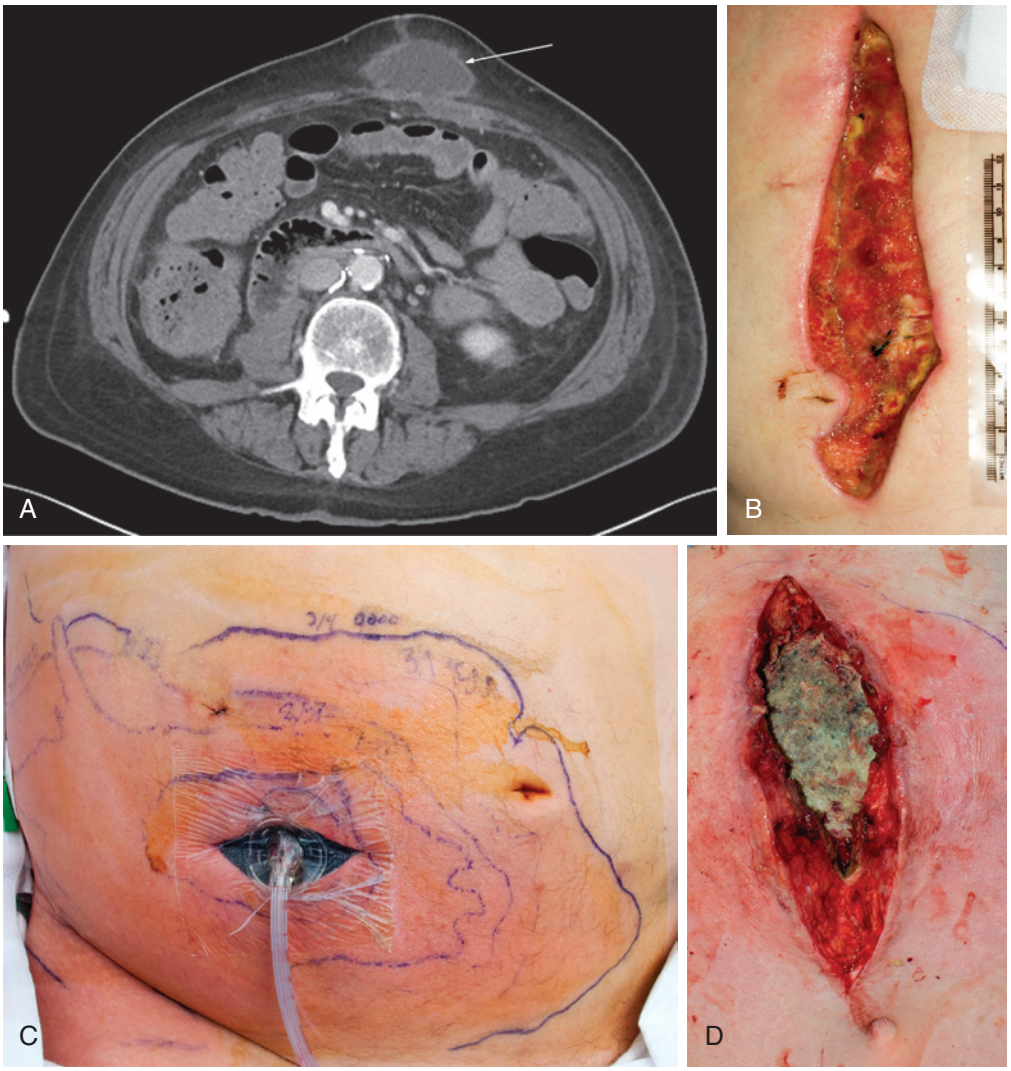


Figure 9.1 Selected wound complications. A, Seroma (arrow) as seen on postoperative cross-sectional imaging. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) B, Superficial surgical site infection (SSI) healing by secondary intention. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) C, Superficial SSI managed with vacuum-assisted closure with surrounding cellulitis. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) D, Fascial wound dehiscence. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

Seromas are located under the incision, above the fascial layer, and directly beneath the dermis of the skin. They are more likely to occur when large tissue flaps are mobilized or when extensive lymphadenectomy is performed, such as during axillary[2] or inguinal lymph node dissection.[3] Thus, efforts to limit the extent of dissection where feasible without compromising cancer control such as sentinel lymph node procedures[4] or preservation of the saphenous vein during inguinal lymphadenectomy[5,6] may reduce the risk of seroma formation.

PREVENTION AND MANAGEMENT

Most postoperative seromas are discovered incidentally and require no active intervention. However, when large or symptomatic, seromas can be evacuated by opening the overlying skin edges, packing the wound with sterile saline-soaked gauze, and allowing the wound to heal by secondary intention. Seromas that develop under flaps (i.e., after inguinal lymph node dissection), however, may be more difficult to manage because these have the potential to damage the delicate vascular supply to the flap. Therefore, in incisions that involve extensive skin flaps, placement of closed-suction drains is typically performed and recommended. These drains are left in place until their output decreases to a minimal amount (typically <30 mL in a 24-hour period). Pressure dressings may be useful postoperatively when seroma formation is of concern. Occasionally, premature removal of the drains may allow a seroma to develop, and percutaneous aspiration or drain placement may be required.

Hematomoa

PATHOGENESIS AND CLINICAL FEATURES

A *hematoma* is a collection of blood in or near a recent surgical incision. Hematomas typically occur in the subcutaneous space, but they may also occur deeper in the incision, such as in the rectus sheath. Wound hematomas are most often caused by inadequate hemostasis after the skin has been closed. Many factors contribute to the formation of hematomas. First, hemostasis at the time of wound closure may be inadequate. Extra care should be taken in patients who are hypotensive or in shock at the time of wound closure. Additionally, the use of epinephrine may mask small bleeding vessels during closure. Postoperatively, anticoagulants such as aspirin, nonsteroidal antiinflammatory drugs, heparin, and warfarin also increase the likelihood of postoperative bleeding and therefore should be used with care in the perioperative period. Finally, a host of disease processes may be present that may predispose patients to the development of hematomas, including myeloproliferative disorders, renal or hepatic insufficiency, deficiency of clotting factors, and platelet dysfunction.

Hematomas usually manifest by ecchymosis of the overlying skin, localized wound swelling, pain or pressure, and drainage of blood from the surgical site. The diagnosis can be confirmed by inspection, palpation, and gentle probing of the wound. If these measures prove insufficient, ultrasound evaluation can be useful to delineate the hematoma.[7]

In addition, large rectus sheath hematomas may manifest with signs of significant hemorrhage, including hemodynamic shock. Often these hematomas result in large ecchymoses that track subcutaneously a long distance from the patient's surgical site. Large hematomas that collect in the retroperitoneum or rectus sheath may cause paralytic ileus, anemia, and ongoing bleeding resulting from the consumption of coagulation factors. One of the most common problems associated with the development of a surgical hematoma is the risk of secondary infection. Blood is a good medium for growth of bacteria that may infiltrate the hematoma and result in a substantial surgical site infection (SSI).

PREVENTION AND MANAGEMENT

The most important factor in the prevention of wound hematoma is meticulous hemostasis at the time of closure of the subcutaneous tissue. Prevention is also facilitated by correction of all clotting abnormalities preoperatively and by discontinuing all medications that can prolong the bleeding time. In addition, wounds that involve large skin flaps or those with large potential spaces in which blood could collect should be drained with a closed-suction surgical drain until the output of these drains decreases. Management of wound hematomas is similar to management of wound seromas, discussed earlier.

Surgical Site Infection

Since the development of modern surgical technique and the innovations of Joseph Lister, surgeons have battled microbial infection. However, despite advances in antimicrobial therapy, aseptic technique, and perioperative patient management, SSIs continue to be the most common infectious complications suffered by surgical patients. Monitoring for these complications is even more complex because shorter hospital stays, outpatient surgery, and the mobility of patients who often see several physicians during the recovery period may affect the rates of complication reporting.[8] In healthy, nonobese patients, the overall SSI rate is estimated at 2.5% of all open surgical procedures, whereas this rate can be many-fold higher in patients with additional risk factors.

The impact of these infections is not insignificant. From an economic standpoint, patients with SSI often require extended hospital stays, additional nursing care, wound supplies, and possibly additional surgical procedures.[9] The estimated cost of this additional care can exceed $30,000 in patients with complicated infections.[10] Moreover, SSIs have significant quality of life implications for patients who may require weeks to months of additional treatment following a surgical procedure. Finally, some series have linked SSIs to an overall increase in postoperative mortality.[11,12]

DEFINITION

The term *surgical site infection* distinguishes a postoperative infection from a traumatic wound infection. The Centers for Disease Control and Prevention (CDC) developed a universal nomenclature for SSIs that involves categorization

according to the depth of infection (Fig. 9.2).[13] Infections that are confined to the skin and subcutaneous tissue (above the fascia) are considered *superficial incisional SSIs*. These infections account for the majority of all SSIs. Infections that involve the deep soft tissue (below the fascia) are termed *deep incisional SSIs*. Deep incisional SSIs include postoperative necrotizing fasciitis and osteomyelitis. Finally, an infection that involves an organ space that was manipulated during a procedure is termed an *organ space SSI*. Organ space SSIs may include peritonitis or other infections that involve the cavitary space entered during the procedure. Usually these infections are diagnosed within 30 days of the procedure. An exception to this rule is the case of implanted material, when SSIs are recorded up to 1 year from the surgical procedure and appear to be related to the operation.[13]

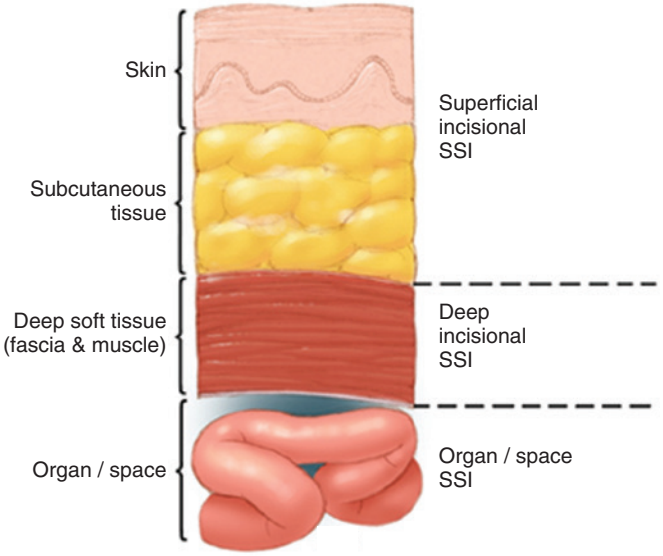


Figure 9.2 Centers for Disease Control and Prevention classification of surgical site infection (SSI). Superficial incisional SSIs are limited to skin and subcutaneous tissues and deep incisional SSIs involve muscle and fascia, whereas organ space SSIs include infections within the cavitary space of the procedure. (Copyright © 2007, Mayo.)

RISK STRATIFICATION

The development of an SSI depends on complex interactions between the pathogenic organism and the host's local and systemic defense mechanisms. Factors influencing the pathogenic organism include the virulence of the contaminating organism itself and the number of organisms inoculated into the wound. In 1964, the National Research Council (NRC) of the National Academy of Sciences reported on a study designed to evaluate the effect of ultraviolet irradiation on postoperative infections.[14] Although this study did not reach its desired end point, it was the first effort to categorize incisions based on the estimated degree of bacterial contamination. The four categories of incision described by the NRC (Table 9.1) remain the most widely accepted classification of surgical wounds to date, and the system remains useful to estimate the risk of SSI, predict pathogens, and determine the need for antimicrobial prophylaxis. This effort represented the first connection between the contaminating flora at various surgical sites and the subsequent infecting pathogens:

Class I, or clean, wounds: Those wounds in which only skin flora are likely to contaminate the operative field because no hollow viscus has been entered. The risk of infection in these cases is low (0.5–2%). A subset of class I wounds, class I_D, consists of wounds in which prosthetic material is implanted. These wounds are classified differently because, although the incidence of infection is also low, the consequences of the infection can be dire and may obviate the entire purpose of the procedure.

Class II, or clean-contaminated, wounds: Those wounds in which a hollow viscus likely to harbor bacteria is entered under controlled circumstances. In these cases, both skin flora and microbes within the viscus may contribute to the SSI and thus the incidence of infection is higher (2–5%).

Class III, or contaminated, wounds: Those wounds in which substantial microbial contamination exists and the risk of infection is even greater (5–15%), particularly if the skin is closed.

Class IV, or dirty-infected, wounds: Those wounds in which the wound is infected preoperatively and the organisms

Table 9.1 Surgical Wound Classification

Classification	Wound Description	Example	Definition
Class I	Clean	Varicocele ligation; herniorrhaphy	An uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, or uninfected genitourinary tract is not entered; in addition, clean wounds are primarily closed and, if necessary, drained with closed drainage
Class I_D	Clean; prosthetic material implanted	Penile prosthesis implantation	Same as class I (clean), with the exception of placement of prosthetic material
Class II	Clean-contaminated	Radical prostatectomy	Operative wounds in which the respiratory, alimentary, or genitourinary tract is entered under controlled circumstances and with minimal contamination
Class III	Contaminated	Radical cystectomy with stool spillage	Open, fresh, accidental wounds; in addition, wounds with a major break in sterile technique or gross spillage from the gastrointestinal tract and incisions in which acute nonpurulent inflammation is encountered
Class IV	Dirty-infected	Perineal debridement for Fournier's gangrene	Old, traumatic wounds with devitalized tissue and those in which purulent infection is encountered

causing the postoperative infection are presumed to be present before the surgical procedure.

In an effort to improve this risk stratification for SSIs the CDC introduced the National Nosocomial Infection Surveillance (NNIS) risk index.[15] The NNIS risk index incorporates additional patient- and procedure-related factors into the previously described wound classification. It is operation specific and assigns points based on patient-related risk factors (as defined by the American Society of Anesthesiologists preoperative assessment score), the duration of the operation, and the degree of microbial contamination of the incision. The duration of the operation is important because lengthy procedures may result in increased exposure to microbial contamination as well as compromised local defenses resulting from desiccation, hypothermia, and lower concentrations of prophylactic antibiotics.

Since the NNIS risk index was produced, additional risk factors for SSIs have been identified. For example, hypothermia has been identified as an independent risk factor for infection, and therefore maintenance of normothermia is an important aspect of intraoperative and postoperative care.[16] Strict glucose control has been independently associated with decreased wound infection rates as well as with decreased mortality in an intensive care setting.[17] Serum albumin level has long been identified as an important risk factor because it reflects a wide range of comorbid conditions that contribute to wound healing.[18] Other important risk factors are age, vascular insufficiency, diabetes, radiation, preoperative smoking, and obesity.

MICROBIOLOGY

Endogenous pathogenic organisms implicated in SSI most commonly come from the patient's skin, alimentary tract, or genitourinary tract. The patient's microflora may be altered by preoperative admission to the hospital. In fact, a demonstrable shift in the microbial environment toward more resistant bacterial species occurs within 48 to 72 hours of hospital admission.[9,19] Exogenous contamination can be minimized by strictly following aseptic technique and maintaining a sterile operating room environment.

The most common organisms isolated from surgical sites remain gram-positive cocci, specifically *Staphylococcus aureus* (Table 9.2). However, gram-negative infections are common in class II wounds. It is important to recognize the type of infection associated with various operative sites to select appropriate antimicrobial prophylaxis.

Table 9.2 Prevalence of Organisms Isolated From Surgical Sites

Organism	Percentage (%)
Staphylococcus aureus	26.9
Escherichia coli	18.8
Streptococcus epidermidis	10.1
Pseudomonas aeruginosa	9.6
Enterococcus faecalis	3.8
Enterococcus faecium	3.8
Proteus mirabilis	3.4
Candida albicans	3.0
Klebsiella pneumoniae	1.5

PREVENTION

Preoperative and Intraoperative Techniques

Prevention of infection in the surgical wound begins by reducing the potential number of microbial contaminants that have access to the wound. Therefore whenever possible, one should identify and treat all infections before surgical intervention. As discussed earlier, lengthy preoperative hospitalizations can increase bacterial antimicrobial resistance and can make any future SSIs more difficult to manage.[19] Patients should be encouraged to stop use of tobacco products for ≥30 days before the operation.[20]

The value of preoperative bowel preparation for reducing SSIs has been debated because several randomized trials[21–24] and meta-analyses[25] demonstrated an increased rate of anastomotic leakage and wound complications when mechanical bowel preparations were used. Indeed, evidence indicates that preoperative bowel preparation is associated with increased stool spillage intraoperatively.[26] Therefore we no longer routinely utilize mechanical bowel preparation for patients undergoing procedures involving bowel interposition.

When the patient reaches the operating room, surgical preparation should consist of an appropriate antiseptic agent for skin preparation. Removal of hair at the surgical site can create nicks and cuts in the skin that may become colonized and increase postoperative infection rates.[27] The CDC recommends that hair not be removed unless excess hair at the operative site would interfere with the operation.[13] When necessary, hair removal should be performed with clippers, rather than razors, because razors are associated with more frequent epithelial damage. Some evidence indicates that the hair should be removed as close to the surgical time as possible.

Intraoperative strategies to prevent wound infection include aseptic technique to reduce the microbial inoculum as well as good surgical practice to minimize dead space and devitalized tissue. An adequate preoperative surgical scrub of at least 2 to 5 minutes should be performed for surgical procedures. Instruments should be adequately sterilized, and efforts should be made to avoid breaks in aseptic technique. During the procedure, gentle handling of the tissue minimizes desiccation and necrosis that may serve as a nidus of infection. Electrocautery was thought to increase the incidence of wound complications because of devitalized tissue. However, more recent studies[28,29] did not show a relationship, and electrocautery may be used according to the surgeon's preference. Foreign bodies such as staples and sutures may provide a nidus of infection, and their use must be weighed against the risks of poor hemostasis and hematoma formation.

Antimicrobial Prophylaxis

The purpose of antimicrobial prophylaxis is to reduce microbial contamination of the incision and to decrease the

incidence of SSI. Surgeons have recognized the importance of antimicrobial prophylaxis in the prevention of SSI for many years.[30–32] For optimal prophylaxis, an antibiotic with a targeted spectrum should be administered at sufficiently high concentrations in serum, tissue, and the surgical wound during the entire time that the incision is open and at risk for bacterial contamination.[33]

To optimize the effectiveness of antibiotic prophylaxis, the antibiotic should be given approximately 60 minutes before surgical incision and dosed according to body mass. In lengthy cases, the antibiotic will need to be readministered approximately every two half-lives of the drug, at which point only 25% of the drug remains in active circulation. In cases with excessive blood loss, an additional dose should be given for every 4 U of estimated blood loss.

Antibiotics, when given in a prophylactic setting, should be discontinued within 24 hours of the procedure.[34] Antibiotics given too late (<30 minutes before surgical incision) do not reach effective tissue concentrations and are less effective in the prevention of SSI,[35] whereas antibiotics given too long afterward (>24 hours after the procedure) increase the incidence of bacterial resistance[36] and raise the economic cost of therapy[37] without decreasing the rate of SSI.

Prophylaxis is recommended for all class II (clean contaminated) wounds and for class I_D (clean) wounds in which prosthetic material or a vascular graft is implanted because the consequences of infection are serious in these instances. The routine use of prophylactic antibiotics is less clear in elective class I cases with no prosthetic material. In addition, patients with class III or IV wounds are considered to have an infected wound, and most of these patients are treated with antibiotics empirically.

DIAGNOSIS AND MANAGEMENT

Most SSIs manifest within 4 to 8 days of the surgical procedure. However, they may manifest within 30 days of the operation or up to 1 year in cases with implanted prosthetic material. This finding implies that, in the current medical environment of outpatient surgery or early discharge, most of these infections occur in the outpatient setting.[8] This implication emphasizes the importance of patient education in the postoperative period. Patients should be aware of the signs and symptoms of SSI and should know when to seek additional care.

The diagnosis of SSI is clinical and has been described for as long as surgical procedures have been performed. Classically, the most common symptoms have been described (in Latin) as *rubor* ("erythema"), *dolor* ("pain"), *tumor* ("induration"), and *calor* ("warmth"). Some patients may also note drainage from the wound or separation of the skin closure. If the SSI is not treated, systemic symptoms may develop, including fever (38–39°C), fatigue, leukocytosis, and increased heart rate.

The management of SSI depends on the extent and type of infection. Drainage and debridement have been and remain the cornerstones of management. Superficial SSIs are treated by opening the incision to provide adequate drainage. A small piece of saline-soaked gauze may be placed in the wound to serve as a wick and to prevent closure of the skin while allowing deeper aspects of the wound to heal by secondary intention. Wet-to-dry dressing changes have been a staple of wound care after SSI, although it may take several weeks to months for the wound to heal by secondary intention (see Fig. 9.1B). A culture and Gram stain may identify the offending organism, although these methods are not always necessary. In the setting of superficial SSI, antibiotics need be given only when patients are at risk for systemic dissemination of the infection. Severe infections, such as necrotizing fasciitis, represent surgical emergencies, and patients should be taken immediately back to the operating room for wide debridement. The identification of only "dishwater" pus, subcutaneous crepitus, or sepsis should alert the clinician to the possibility of necrotizing fasciitis. These infections progress rapidly and are caused by either *Clostridium perfringens* or group A β-hemolytic streptococci.

The development of vacuum-assisted closure has eased the process of multiple daily dressing changes (see Fig. 9.1C). Vacuum-assisted closure was designed to promote healing of large wounds by constant or oscillating application of negative pressure. This negative pressure promises to increase local blood flow, control exudates, and reduce edema of the surrounding tissue.[38–40] In our experience, these negative pressure techniques have proved useful in treating large, chronic wounds. However, their use should be limited when wounds are near conduits, anastomoses, and neobladders because in our experience, they may be associated with an increased rate of cutaneous fistula formation.

Wound Dehiscence

PATHOGENESIS AND CLINICAL FEATURES

Surgical wound dehiscence (see Fig. 9.1D) is one of the most alarming complications faced by abdominal surgeons. Put simply, a *dehiscence* represents the mechanical failure of wound healing and is defined as a separation of the facial layers early in the postoperative period. *Evisceration,* in turn, is a related term referring to the extrusion of peritoneal contents through the dehisced wound. Dehiscence is of great concern because it may rapidly lead to evisceration. Abdominal dehiscence with evisceration has been associated with a mortality rate nearing 50%.[41] When diagnosed early in the postoperative period, complete wound dehiscence almost always requires a return to the operating room for fascial closure or repair. However, small partial wound dehiscences that are diagnosed >2 weeks postoperatively may often be watched with delayed repair of the resultant incisional hernia, because the risk of evisceration is very low in such patients.

Unfortunately, wound dehiscence frequently occurs without warning. Up to 80% of the time, it manifests as sudden, dramatic drainage of a large volume of clear, serous fluid from the incision. Patients may also note a pulling or ripping sensation. This often occurs when the patient is standing or changing positions, because the pressure on the incision is greatest at these times. The diagnosis is then confirmed by gently probing the incision with a sterile, cotton-tipped applicator to determine the integrity of the fascia. If clinical suspicion remains despite equivocal physical examination findings, imaging studies such as

Table 9.3 Risk Factors Associated With Wound Dehiscence

Preoperative Risk Factors	Intraoperative and Postoperative Risk Factors
Malnutrition	Technical error with fascial closure
Anemia	Emergency procedures
Hypoproteinemia	Wound complications (infection, seroma, hematoma)
Obesity	
Comorbid disease (e.g., diabetes, renal failure, chemotherapy, irradiation)	
Increased intraabdominal pressure (e.g., coughing, straining, ascites)	
Advanced age	
Long-term corticosteroid use	

ultrasound or computed tomography can be used. When a large segment of the incision is open, immediate plans for closure in the operating room should be made. In the event of evisceration, the eviscerated intraperitoneal contents should be covered with a sterile saline moistened towel until an emergency operation can be performed.

Numerous factors can contribute to wound dehiscence (Table 9.3). However, despite advances in suture material and perioperative care, the incidence of abdominal fascial dehiscence has remained steady at nearly 1% of abdominal wounds.[42,43] Other factors that contribute to wound dehiscence remain. Obesity, for example, is associated with increased difficulty in identifying the fascia and in closing the incision. Corticosteroids, over long periods, can decrease the tensile strength of healing wounds.[44] Patients with cancer are more likely to have problems with wound healing, because these patients are more likely to have a contaminated wound and have undergone previous irradiation or chemotherapy.[45] Radiation causes obliterative sclerosing endarteritis that can decrease the microvascular arterial supply to the wound.[46] Malnourished patients nearly uniformly have decreased protein synthesis and turnover, which lead to poorer fascial integrity. Finally, diabetic patients encounter more healing problems than do patients without diabetes and have a greater risk of wound dehiscence.[41] The likely reason is that diabetic patients have less collagen synthesis and deposition, decreased wound breaking strength, and impaired leukocyte function.

SUTURE SELECTION AND TECHNIQUE

Wounds have <5% of normal tissue strength during the first postoperative week and may not ever develop normal tensile strength. In fact, studies have demonstrated that abdominal fascia regains 50% to 59% of this original tensile strength at 7 weeks and 70% to 90% at 20 weeks but may never exceed 93% of uninterrupted fascia.[47,48] Therefore initial postoperative wound security depends solely on suture strength and technique of closure.[49] As such, the choice of suture material is of critical importance in closing abdominal surgical wounds. The suture material should be strong enough to reapproximate the tissue and keep the wound intact during normal postoperative activity.

Numerous suture materials are available for wound closure. These sutures can be classified as natural or synthetic as well as rapidly absorbable, slowly absorbable, and nonabsorbable. Synthetic material has the advantages of being more uniform, inducing less tissue reaction, having greater tensile strength for a given diameter, and eliminating the risk of disease transmission. In 2001 the United Kingdom eliminated the use of catgut suture because of the risk of transmission of bovine spongiform encephalopathy (BSE, or mad cow disease).

Nonabsorbable sutures have been widely used to close abdominal incisions for many years. However, stainless steel wire and braided silk, once commonplace, have been replaced by more modern suture materials. Nonabsorbable monofilament sutures are associated with less tissue reaction[50] and more resistance to infection[51] than are absorbable sutures. However, they are associated with a higher incidence of sinus formation and long-term wound pain.[52–55] The primary benefit of nonabsorbable sutures is that they maintain tensile strength throughout the process of wound healing.

Absorbable sutures are designed to reapproximate the fascia through the initial phases of wound healing until the fascia itself has regained enough tensile strength. Rapidly absorbable sutures are not recommended for closure of abdominal incisions because this suture type has been demonstrated to have a higher incidence of wound dehiscence[56] and postoperative hernia formation[55,57] when compared with nonabsorbable sutures. However, slowly absorbable sutures, such as polydioxanone (PDS) and polyglyconate (Maxon), have been shown to cause less incisional pain and suture sinuses, with no effect on the long-term hernia rate. Additionally, these newer-generation monofilament sutures are more resistant to infection than are multifilament sutures.[58,59] They are degraded by hydrolysis and are not as subject to enhanced absorption resulting from bacterial enzymatic activity.[60]

When a suture is placed through the fascia in the operating room, wound dehiscence has three potential causes:

1. The suture may break
2. The knot may slip
3. The suture may cut through the tissue.

Several studies have demonstrated that suture breakage and knot failure are rarely the source of wound dehiscences, and in the majority of wounds that have dehisced, the suture and knots are intact but the suture has torn through the fascia.[49,61] This finding brings to light the importance of suture diameter because smaller-diameter sutures are associated with a greater likelihood of tearing through tissue.[43,62,63] Therefore most sutures used for abdominal wound closure are number 0 or larger. Additionally, the use of continuous running looped sutures has gained popularity as a method to increase the speed and tensile strength of wound closure. A double-looped closure has been demonstrated to be the strongest method of wound closure, but it has been associated with increased pulmonary complications, potentially because of decreased abdominal compliance.[43]

Surgical dictum states that sutures should be placed ≥1 cm from the fascial edge while advancing ≤1 cm with each throw. This recommendation results from concern for thermal injury related to the use of electrocautery on the fascial edge. Jenkins[64] demonstrated that the length of a midline laparotomy can increase up to 30% in the postoperative period as a result of elasticity and increased intra-abdominal pressure. Therefore it is important when closing using a running suture that the suture is of adequate length. Investigators have demonstrated that wounds that have been closed with a suture length that is twice as long as the wound have a higher rate of wound dehiscence[64] than do wounds closed with suture that is four times the length of the wound. This concept is referred to as the *suture-to-wound length ratio,* and a ratio of at least 4 : 1 provides good wound security.[65–68] Theoretically, this approach affords adequate approximation of the fascial tissues while minimizing the ischemic effects of increased tension along the suture line.

LAYERED VERSUS MASS CLOSURE

Layered closure of the abdominal wound involves separate closure of each of the distinct fascial layers with or without closure of the peritoneum. *Mass closure,* or Smead-Jones closure, is the closure of all layers of the abdominal wall, except the skin, as a single structure. Classically, this approach involved interrupted sutures. However, no benefit has been demonstrated over a continuous suture technique. Layered closure was believed to decrease intraperitoneal adhesions, increase wound strength, and promote hemostasis. These effects were especially noted with paramedian incisions,[69–71] which currently are used less frequently than are muscle-splitting midline incisions. However, several prospective, randomized studies[54,72] and large meta-analyses[57,73,74] demonstrated that layered closure is associated with higher rates of dehiscence and prolonged operative times as compared with mass closure. Separate peritoneal closure, in particular, has been associated with more intraperitoneal adhesions, increased operative times, and obscured fascial closure.[75–77] Furthermore, evidence indicates that the peritoneum re-epithelializes within 48 to 72 hours without closure,[78] and separate closure of this layer is unnecessary.

Retention sutures are sutures that are placed through all layers of the abdomen, including skin. They are often secured around a piece of rubber tubing and tied down (Fig. 9.3). Although historically they were used to decrease the incidence of abdominal dehiscence in patients at high risk, more recent studies did not demonstrate a beneficial effect on the rate of dehiscence. These sutures have also been associated with increased pain and inconvenience.[79]

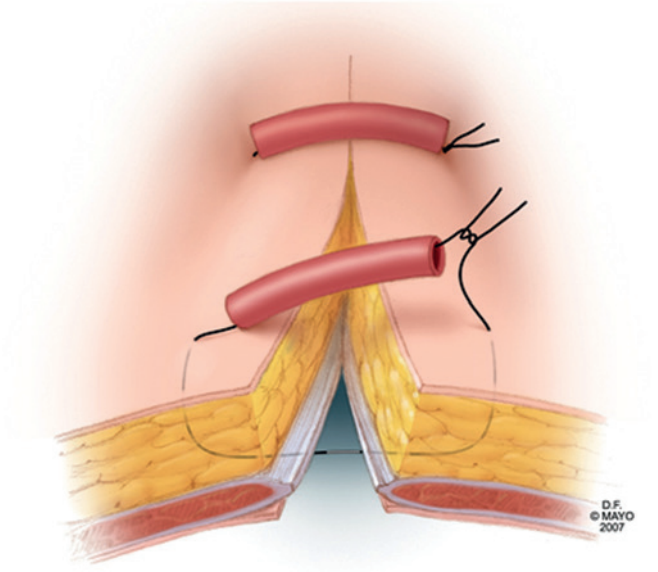


Figure 9.3 Retention sutures are placed through all layers of the abdominal wall and are secured around rubber tubing. (Copyright © 2007, Mayo.)

Nerve/Plexus Injuries

Nerve injury during urologic surgery may be caused by direct surgical trauma (i.e., nerve transection) or by stretch and compression of nerves from improper patient positioning or retractor placement. With regard to injuries caused by surgical trauma, all surgical incisions risk division of cutaneous sensory nerves and thereby may result in abdominal wall neuralgias or sensory deficits.[80] These complications are likely underreported by physicians, and therefore the incidence of such events is difficult to quantitate. The following discussion is a review of nerve injuries resulting from stretch and compression.

Improper patient positioning or retractor placement may cause stretch and compression of nerves that manifest as a deficit in postoperative neurologic function. In addition, ischemic injury compromising the blood supply of a nerve (i.e., ischemia of the intraneural vasa nervorum) may result in nerve injury as well.[81] Anesthetized patients have reduced muscle tone and are unable to report the discomfort of improper positioning, factors that place these patients at particular risk of injury. Although such nerve injuries are usually temporary, they significantly affect patients' quality of life and may result in permanently debilitating complications. For example, nerve injuries may limit postoperative ambulation and thereby increase the risk for thromboembolic events. Therefore a thorough understanding of the risk factors, presentation, and management of nerve injuries associated with common urologic procedures is essential for the urologic surgeon.

Although nerve injuries may occur during any of a variety of urologic procedures, the most common circumstances in which we have encountered these events involve brachial plexus injuries after surgery in the flank position, femoral nerve injuries from radical pelvic surgery, and lower extremity nerve injury from procedures in the lithotomy position. Therefore, these injuries are the focus of this section.

UPPER EXTREMITY NERVE INJURIES

Upper extremity nerve injuries during urologic surgery most often are the result of injuries to the brachial plexus, which contains the C5–T1 nerve roots and runs between the prevertebral fascia and the axillary fascia of the arm.

This plexus supplies multiple nerve branches including the musculocutaneous, axillary, radial, median, and ulnar nerves. The brachial plexus is particularly vulnerable to injury because of its lack of mobility, being fixed to the vertebrae, prevertebral fascia, and axillary fascia, as well as its proximity to bony structures, including the first rib, clavicle, coracoid process, and the head of the humerus.[82] Injuries to the brachial plexus may be the result of direct trauma, excessive stretching, external pressure, or a combination of these factors. In our experience, although brachial plexus injuries have been reported to result from excessive extension and external rotation during surgical procedures in the supine position (Fig. 9.4), including radical prostatectomy,[83] most brachial plexus injuries occur during procedures in the flank position, which is commonly used for procedures involving the kidney and retroperitoneum.

Given that the flank position is one of the most common positions for urologic surgery, we describe here our technique of flank positioning, which aims to achieve optimum operative exposure while avoiding neurologic injury (Fig. 9.5). After general anesthesia is established, patients should be placed in the lateral decubitus position with the nonoperative side against the operating table. The lower leg is then flexed at the knee and hip, the upper leg is kept straight, and pillows are placed between the knees to prevent contact of potential pressure points. Heels and knees are padded, and the patient is secured to the operating table using either cloth tape or Velcro straps. The head is padded as well to prevent angulation of the neck. Indeed, excessive dorsal extension or lateral flexion of the neck risks stretching of the brachial plexus to the opposite side of the patient between the fixed points at the transverse processes of the cervical vertebrae and the axillary fascia of the upper arm.[81]

The downside arm is then placed at an approximately 90-degree angle to the table and is secured to the armboard. Suspension of the upside arm (i.e., from an anesthesia screen, from a bar anchored to the operating table, or on blankets placed over the downside arm) must be done with care because excessive tension or abduction may stretch the brachial plexus around the clavicle and compress the nerves against the tendon of the pectoralis minor muscle.[81] A somewhat misnamed "axillary roll," which should more correctly be considered a chest roll, is then placed just beneath the true axilla. In fact, placement of this roll (we use a blanket) within the true axilla may result in compressive injury to the brachial plexus or vascular obstruction of the upper extremity.

After securing the patient to the bed, we then flex the operating table and raise the kidney rest, which should lie just above the iliac crest, until the muscles of the flank become tight.[81] This maneuver maximizes separation of the costal margin and iliac crest for surgery while minimizing the risk of vena caval compression.

Despite vigilant attention to patient positioning, injuries to the brachial plexus may occur during procedures in the

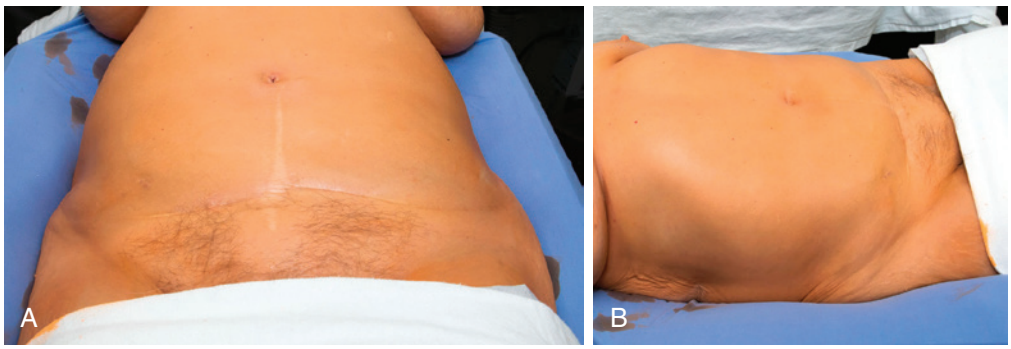


Figure 9.4 Supine position for midline approach. A, Anterior view. The arms are tucked at the sides and supported by toboggans. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) B, Lateral view. The arms are tucked at the sides and supported by toboggans. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

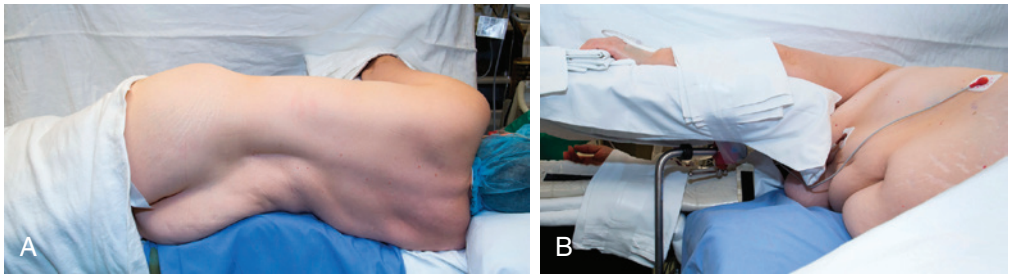


Figure 9.5 Flank position. A, Posterior view of flank position. The patient is placed in the lateral decubitus position with the head padded to prevent excessive neck flexion or extension. The lower leg is flexed at the knee and hip, with the heel and knee padded for protection. The upper leg is straight, and a pillow is placed between the upper and lower legs at the knees. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) B, The lower arm is supported on a gel-padded armboard at an approximately 90-degree angle and secured. The upper arm is supported in a padded armrest. The torso is positioned so that the upper arm rests in a neutral position. An axillary roll is placed underneath the chest just below the axilla, and the table is flexed and the kidney rest raised to expand the flank. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

flank position. Injuries to the brachial plexus of the downside arm during flank positioning, for example, are most often compressive, although stretch injuries may occur if the dependent arm shifts position during the surgical procedure.[81] Brachial plexus injuries of the upside arm in the flank position, meanwhile, are most often the result of abduction, extension, and external rotation of the humerus that stretch the plexus around the clavicle, the tendon of the pectoralis minor, and the head of the humerus.[84]

The presentation of brachial plexus injuries varies somewhat with the level of injury but most often involves some degree of weakness of the affected upper extremity, including the deltoid, supraspinatus, biceps, brachioradialis, and triceps muscles, as well as the wrist and finger flexors and extensors.[82] Patients may also report decreased pinprick sensation along a dermatomal (i.e., C7–T1) distribution. Deep tendon reflexes of the biceps and brachioradialis muscles are characteristically absent on physical examination. Peripheral branches of the brachial plexus may be injured after their exit from the axilla, and these injuries may manifest as isolated nerve deficits; for example, the median and ulnar nerves can be damaged if the arm is allowed to hang unsupported over the edge of the operating table, whereas the radial nerve of the downside arm may be injured if the arm is pushed cephalad against the vertical bar of the anesthesia screen, thus compressing the nerve between the humerus and the bar.[81] The role of electromyography in the evaluation of patients with a suspected nerve injury is discussed further later in the section on femoral nerve injuries.

Management of a suspected brachial plexus injury includes careful neurologic examination, protection of potentially hypesthetic skin from injury, and physical therapy consultation to prevent muscle wasting.[82] Other treatments including intermittent galvanic stimulation to the affected muscle and surgical repair have been described.[82,85] We have seen considerable variability in the course of recovery of function after brachial plexus injury, from hours to months. Nevertheless, we, as others,[82,86] have noted that sensation consistently returns before motor function, and that the lower nerve roots recover function before the upper nerve roots.

LOWER EXTREMITY NERVE INJURIES

Various injuries to the nerves that innervate the lower extremities have been described during urologic procedures. These injuries include direct trauma to the nerves, such as intraoperative transection, injuries that relate to patient positioning, and injuries that result from retractor compression. Here, we separate the discussion into injuries of the femoral nerve, which may occur by any of these mechanisms but are most commonly the result of compression from retractor placement, and nerve injuries related to the lithotomy position that may involve the femoral nerve but often affect other nerves of the lower extremity.

INJURIES TO THE FEMORAL NERVE

The femoral nerve, which arises from the second through the fourth lumbar nerve roots, represents the largest branch of the lumbar nerve plexus. The femoral nerve is formed within the body of the psoas major muscle and then passes inferolaterally within the psoas before emerging just superior to the inguinal ligament, in a groove between the psoas and iliacus muscles.[87] The blood supply to the extrapelvic portion of the femoral nerve is the lateral femoral circumflex artery, whereas the intrapelvic component of the femoral nerve is supplied by the iliolumbar and deep circumflex iliac arteries.[88] A more extensive collateral blood supply to the right femoral nerve has been demonstrated,[89] a finding suggesting that the left femoral nerve may be more susceptible to ischemic injury than is the right.[88]

The femoral nerve contains both sensory and motor components, including the sensory branches of the anterior and medial femoral cutaneous nerve, as well as the long saphenous nerve. Motor innervation from the femoral nerve is provided to the psoas, iliacus, quadriceps femoris, pectineus, and sartorius muscles. Therefore injury to the femoral nerve may result in weakness of hip flexion, knee extension, adduction, and external rotation.[88,90,91] Clinically, femoral nerve injuries usually manifest as difficulty with ambulation in the early postoperative period. Patients whose injuries are not recognized before discharge commonly report difficulty in climbing stairs at home.[91] In addition, patients may report numbness and paresthesias of the anteromedial thigh.[92] On physical examination, weakness of the quadriceps muscles and diminished or absent deep tendon reflexes at the knee (patellar reflex) are consistent findings.

Femoral nerve injuries may result from patient positioning, retractor-related compression, or direct operative trauma. Direct injury is usually suspected intraoperatively, and careful inspection along the course of the nerve is recommended in such cases. Positioning-related femoral nerve injuries in urology have most consistently been reported from procedures in the lithotomy position,[93,94] and they are discussed in the next section.

The most common mechanism for femoral nerve injury during urologic procedures, however, is compression of the nerve by self-retaining retractors. This situation typically occurs during prolonged abdominal cases such as radical cystectomy, although injuries have been reported after radical prostatectomy and even perineal prostatectomy.[95] Retractor injuries occur when the blades of the retractor are placed directly on the psoas muscle, where they may compress the nerve directly or indirectly by trapping the nerve against the lateral pelvic wall (Fig. 9.6).[88] In addition, retractor blades may compromise the blood supply to the femoral nerve by compressing the iliolumbar artery.[92] Thin patients, in whom the retractor blades are more likely to compress the psoas muscle, are at particular risk for femoral nerve injury from retractor compression.[96] Moreover, the length of time of retraction has been correlated with the severity of nerve injury.[97] Therefore care should be taken to ensure that retractor blades retract only the rectus muscle and do not sit directly on the psoas muscle. Periodic inspection of retractor placement during the surgical procedure by placing the surgeon's fingers beneath the blades to ensure clearance off the psoas muscle is mandatory to avoid inadvertent compression injury.

The initial evaluation of a suspected femoral nerve injury includes careful documentation of the neurologic findings, along with physical therapy consultation. Immediate

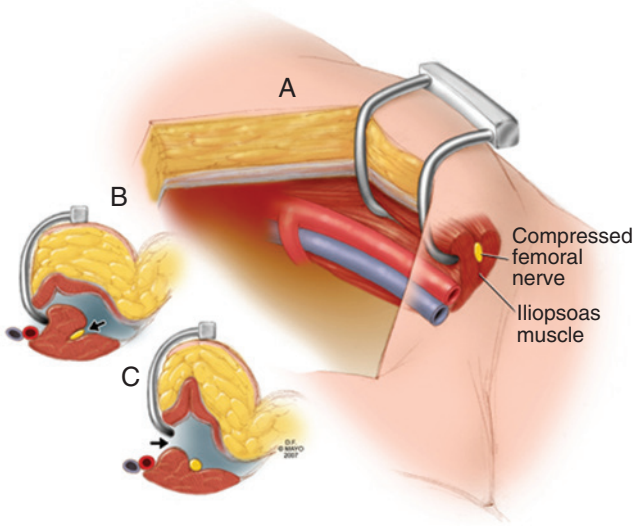


Figure 9.6 Common mechanism of femoral nerve injury by retractor placement. A and B, Compression of the femoral nerve by placement of the retractor along the iliopsoas muscle. C, Correct position of the retractor to retract the rectus muscle only. (Copyright © 2007, Mayo.)

physical therapy helps to prevent muscle atrophy and may decrease the risk of thromboembolic complications associated with prolonged bed rest.[96] Ambulation may be facilitated in the case of femoral nerve injury by locking the ipsilateral knee to compensate for the associated thigh muscle weakness.[88] Although most femoral nerve injuries in our experience are caused by retractor-related compression, nerve compression from pelvic or retroperitoneal hematomas has been described.[88,98] Therefore, if one clinically suspects bleeding, three-dimensional imaging should be obtained as well.

In the setting of a persistent postoperative nerve deficit clinically consistent with a femoral nerve injury, neurologic consultation and an electromyogram to evaluate for anatomic denervation are warranted. Electromyography should be performed ≥3 weeks from the time of injury to maximize its prognostic value.[99] Although the recovery process may be prolonged, compression-related nerve injuries usually resolve over time, and patients regain nerve function. Early return of function has been thought to correlate with full recovery,[91] and sensory lesions are more frequently transient than are motor lesions.

Prevention of femoral nerve injury is paramount because the consequences may significantly affect patients' quality of life. Vigilant attention to patient positioning, limiting surgical time, and periodically inspecting retractor placement are key to avoiding these injuries.

INJURIES RESULTING FROM LITHOTOMY POSITION

Standard lithotomy position requires the patients' legs to be separated from the midline into 30 to 45 degrees of abduction, with the hips flexed until the thighs are angled between 80 and 100 degrees. The patient's legs are placed into stirrups, with the knees bent such that the lower legs are parallel to the plane of the torso.[100] An understanding of potential postoperative complications related to this position is essential to the care of urologic patients. In addition to neurologic complications, which are discussed here, other complications that have been reported after procedures in the lithotomy position include lower extremity compartment syndrome, venous thrombosis, and rhabdomyolysis.[101,102] The frequency of perioperative complications may increase with an exaggerated or "high" lithotomy position because the angle of the hips and lower extremities in this position is even more pronounced.[103]

Neurologic injuries related to the lithotomy position may affect the femoral, sciatic, and common peroneal nerves. One series found that the most common lower extremity neuropathies associated with procedures in the lithotomy position were common peroneal (81%), sciatic (15%), and femoral (4%).[104] Other, less commonly injured nerves include the obturator and femoral cutaneous nerves. A study of 1170 patients operated on in the lithotomy position found postoperative neurapraxic complications in 1% of patients.[103] Age >70 years, operative time >180 minutes, and improper positioning were cited as risk factors for neurologic injury.[103] These findings were supported by a separate investigation, which noted lower extremity neuropathies in 1.5% of 991 patients undergoing procedures in the lithotomy position and found that prolonged (>2 hours) positioning in the lithotomy position was a risk factor for injury.[105] A previous study reported postoperative neurapraxia in 21% of patients undergoing perineal prostatectomy using the exaggerated lithotomy position.[106]

Positioning-related nerve injuries in the lithotomy position have been attributed to overflexion of the hips and knees, which causes stretching and compression of the nerves. For example, hyperabduction of the thighs with external rotation of the hips may lead to injury of the femoral nerve secondary to ischemia from compression of the nerve beneath the inguinal ligament.

The sciatic nerve, meanwhile, is the largest nerve in the body. It arises from the fourth lumbar through the third sacral nerve roots of the lumbosacral plexus and exits the pelvis through the sciatic foramen, traveling through the thigh before dividing in the popliteal fossa into the common peroneal and tibial nerves. The sciatic nerve functions to provide cutaneous innervation to the foot and leg, as well as motor innervation of the biceps femoris (hamstring muscle), leg, and foot.[107]

Excessive stretching of the sciatic nerve by overflexion of the hip and extension of the knee during establishment of the lithotomy position or by shifting of the patient during the procedure may result in injury. In particular, investigators have suggested that excessive hip flexion in the lithotomy position may compress the nerve as it passes through the sciatic notch, thus potentially resulting in ischemic neuropathy.[108,109] The potential sequelae of sciatic injury depend on the location of the insult along the course of the nerve. Injury to the thigh portion of the sciatic nerve, for example, results in difficulties with flexion of the leg, whereas disruption of the tibial nerve abolishes the ankle jerk reflex.

The common peroneal nerve arises from the sciatic nerve behind the knee and then wraps around the head of the fibula before separating into the superficial peroneal, which provides sensory innervation to the lateral leg, and the deep peroneal, which provides motor innervation to the tibialis

anterior that allows dorsiflexion of the foot. Because this nerve is very superficial when it crosses the head of the fibula, it may easily be compressed and injured at this point (i.e., by direct contact of the leg against an immobile, hard support). Therefore padding the lateral leg supports during positioning for lithotomy procedures is recommended. Injury to the peroneal nerve most commonly manifests as foot drop, resulting from an inability to dorsiflex the foot. In addition, patients may experience numbness of the lateral aspect of the lower leg and dorsum of the foot.[109]

Overall, nerve injuries during procedures in the lithotomy position may be minimized by careful attention to proper patient positioning, including padding of exposed peripheral nerves, avoiding unnecessary tension on the hips and knees by checking to see that the muscles of the lower extremity are not taut after the lithotomy position is established, and minimizing operative times. Modifications in stirrup design have also been proposed to help minimize the complications of lithotomy positioning.[110]

INJURIES RELATED TO POSITIONING FOR ROBOTIC SURGERY

Robotic-assisted surgery has undergone rapid dissemination in the last decade and is now the most frequently employed surgical approach for radical prostatectomy,[111] with increasing utilization for renal and bladder surgery as well. While robotic renal surgery may be performed in a modified flank position, robotic-assisted pelvic surgery poses unique considerations for patient positioning (Fig. 9.7) and presents new risks for positioning injuries.[112,113] Notably, the incidence of positioning injuries associated with robotic surgery may be greater than that in conventional laparoscopic or open surgery. For instance, a recent single-institutional study reported a 6.6% incidence of upper or lower extremity injury with robotic urologic surgery,[114] compared with 2.7% for conventional laparoscopic urologic surgery,[80] and 0.3% in open radical prostatectomy.[115] Interestingly, the rate of positioning injury may be greater with upper abdominal or retroperitoneal procedures.[80,114]

Robotic-assisted pelvic surgery is most frequently performed in a modified lithotomy position in conjunction with steep Trendelenberg.[112,113] The arms may be either tucked or abducted on armboards. Accordingly, robotic pelvic surgery carries risks of upper extremity nerve injuries analogous to those discussed above for the supine position, which include injuries to the brachial plexus, as well as median, ulnar, and radial nerves.[116] Careful attention must be paid to arm positioning, as one study noted that 84% of upper extremity injuries were associated with an extremity that was tucked or at the patient's side.[114] Lower extremity nerve injuries may occur from the lithotomy position as discussed above and may include injuries to the common peroneal, sciatic, and femoral nerves.[112,117] Increased operative time has been associated with an increased risk of such injuries.[80,104,118]

The use of steep Trendelenburg presents special considerations to attempts to prevent positioning injuries. For instance, the risk of cephalad patient movement requires careful attention to patient fixation on the operating table. The use of shoulder braces has been discouraged as they may increase the risk of brachial plexus injuries when used improperly.[112,117,119] Alternatively, some surgeons utilize a bean bag[114] or anti-skid material[119] to prevent cephalad migration. Our practice has been to use a gel pad, which when placed directly underneath the patient's back, provides resistance to cephalad migration on the operating table. In addition, the patient is secured using a padded chest strap and further stabilized by the feet anchored in stirrups (Fig. 9.7A).

Robotic surgery in the steep Trendelenburg position also poses unique considerations for the anesthesia team,

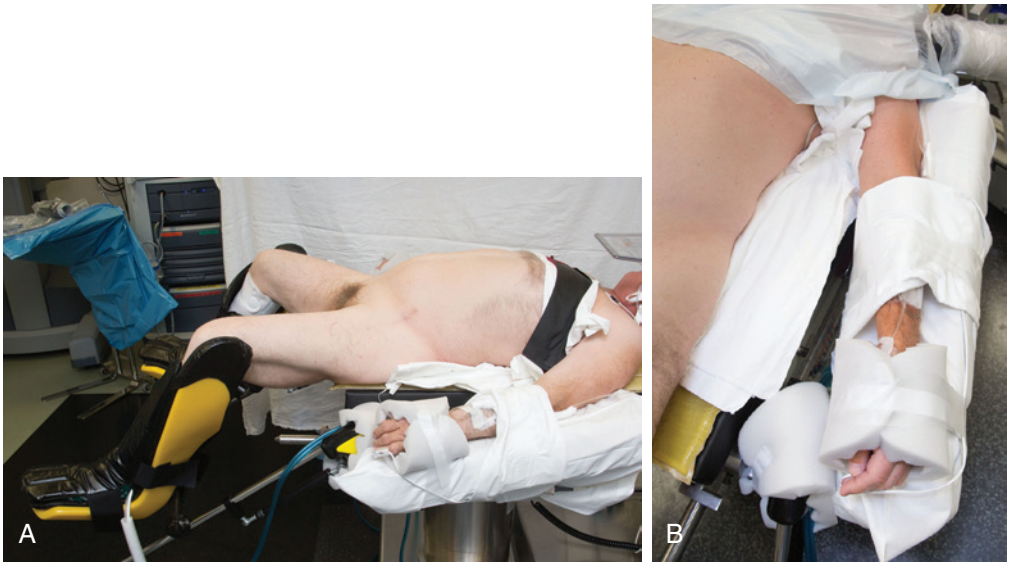


Figure 9.7 Modified lithotomy position for robotic-assisted radical prostatectomy. A, Overview of modified lithotomy position used for robotic-assisted radical prostatectomy. The patient is placed on a nonskid gel pad to prevent cephalad migration during Trendelenburg position and secured using a padded chest strap and stirrups. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) B, The arms are positioned on padded armboards with minimal abduction, with Gelfoam used to protect the wrists. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

including increased difficulty with respiratory gas exchange and ventilation, cardiopulmonary changes related to pneumoperitoneum, and restricted access to the patient.[120–122] Communication between the surgeon and anesthesiologist is essential to ensure patient safety. Robotic surgery in the steep Trendelenburg position has been associated with vision loss from ischemic optic neuropathy.[117,123,124] The mechanism is hypothesized to be related to increased intraocular pressure (IOP) stemming from increased intracranial pressure and disturbed cerebrovascular and ophthalmic circulatory autoregulation.[120,125,126] Duration of surgery in steep Trendelenburg has been identified as a risk factor for increased IOP.

Compartment syndrome and rhabdomyolysis have also been reported related to positioning for robotic surgery.[113,125,127–130] The use of lithotomy position combined with steep Trendelenburg increases risk for both injuries due to direct pressure on muscles in conjunction with reduced perfusion from elevation of lower extremities above the level of the heart. Prolonged hypoxia from compartment syndrome may lead to rhabdomyolysis. Gluteal compartment syndrome has been reported from direct muscle pressure.[128] A recent population-based study of renal surgery reported an increased incidence of rhabdomyolysis with the robotic compared to laparoscopic approach.[131] Several studies have identified obesity and prolonged operative time as risk factors for compartment syndrome and rhabdomyolysis in robotic surgery.[127,130–132]

Prevention of robotic positioning injuries begins with careful attention to positioning of upper and lower extremities as discussed above and coordination with the entire operating room team.[133] Interestingly, a volume–outcome relationship has been described for positioning injuries, including positioning for robotic surgery,[80,118,134] highlighting that experience is an essential component to preventing such injuries. It is also important to recognize that some risk factors for positioning injuries, such as obesity, are not modifiable, whereas others, such as operative time and degree of Trendelenburg, may be modifiable. Specific suggestions for prevention of perioperative peripheral neuropathies have been outlined by the American Society of Anesthesiology.[135] In addition, side docking of the robot has recently been described as a novel approach to reduce risk of positioning injuries associated with either lithotomy position or steep Trendelenberg.[136]

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Chapter 9 Questions

1. When closing fascial wounds using a running suture, the suture length should be at least ____ times the length of the wound:
   a. 1.5
   b. 2
   c. 3
   d. 4
   e. 6

2. Which of the following is not an important factor in reducing the incidence of surgical site infections (SSIs) after radical cystectomy?
   a. Antimicrobial prophylaxis given 60 minutes before incision
   b. Adequate mechanical bowel preparation
   c. Maintenance of normothermia during and after the procedure
   d. Length of preoperative hospitalization
   e. Redosing of the antimicrobial prophylaxis every two half-lives

3. What is the most common nerve injured by self-retaining retractors during open urologic procedures in the supine position?
   a. Common peroneal nerve
   b. Iliolumbar nerve
   c. Obturator nerve
   d. Sciatic nerve
   e. Femoral nerve

4. What is the most likely clinical manifestation of injury to the common peroneal nerve?
   a. Foot drop
   b. Weakness of flexion of the leg
   c. Weakness of hip extension
   d. Numbness of the posterior lower leg and ankle
   e. Weakness of hip adduction

5. Which of the following has been reported as a risk factor for positioning injuries related to robotic surgery?
   a. Steep Trendelenburg position
   b. Increased operative time
   c. Obesity
   d. Abduction of the arms
   e. All of the above

6. A 55-year-old obese male is planned to undergo robotic-assisted laparoscopic prostatectomy. He has a history of previous colon resection with postoperative bowel leak and abscess drainage, and thus prolonged lysis of adhesions is anticipated. The best technique to reduce the likelihood of calf compartment syndrome is:
   a. To carry out staged lysis of adhesions, with return to OR for prostatectomy
   b. To perform procedure in flat supine position, without Trendeleburg
   c. To use compression stockings
   d. To use side docking of the robot
   e. To administer subcutaneous heparin

7. In preventing dehiscence of fascial closure, which of the following techniques should be avoided:
   a. Mass closure
   b. Retention sutures
   c. Peritoneal closure
   d. Use of nonabsorbable suture
   e. Passage of suture 5 mm from cut fascial edge

8. The most common organism found in wound infection cultures is:
   a. *Escherichia coli*
   b. *Candida albicans*
   c. *Staphylococcus aureus*
   d. *Streptococcus epidermidis*
   e. *Klebsiella pneumoniae*

9. The procedure presenting the greatest risk for wound infection is:
   a. Radical prostatectomy
   b. Hydrocelectomy
   c. Penile prosthesis
   d. Cystectomy/ileal conduit
   e. Inguinal lymph node dissection

10. Potential consequences of steep Trendelenburg position utilized for robotic-assisted radical prostatectomy include all of the following except:
    a. Increased intraocular pressure
    b. Increased peak airway pressure
    c. Brachial plexus injury
    d. Hearing loss
    e. Vision loss

Answers

1. **d.** Fascial sutures should be placed at least 1 cm from the fascial edge while advancing no more than 1 cm with each throw. The length of a midline laparotomy may increase up to 30% in the postoperative period due to elasticity of the fascia and increased intraabdominal pressure. Several studies have demonstrated a higher rate of dehiscence and hernia formation when the length of suture used to close the wound is less than four times the length of the wound itself.
2. **b.** Several randomized trials have failed to demonstrate an improved rate of SSI with the use of mechanical bowel preparation. Instead, it may be associated with a higher rate of stool spillage during the procedure. All of the other factors listed have been associated with decreased rates of SSIs.
3. **e.** The femoral nerve arises from the second through fourth lumbar nerve roots. It is then formed within the psoas major muscle and emerges superior to the inguinal ligament. It is most commonly injured by retractors during prolonged abdominal cases when the nerve is compressed against the lateral pelvic wall. The common peroneal nerve is located in the lower extremity. The sciatic nerve arises from the fourth lumbar to third sacral nerve roots and exits the pelvis through the sciatic foramen. It may be injured during the

dorsolithotomy position. The obturator nerve is not commonly injured because of retractor positioning.

4. **a.** The common peroneal nerve is the most common nerve injured in the lithotomy position. It provides motor innervation to the tibialis anterior, which allows dorsiflexion of the foot, and sensory innervation to the lateral leg. Injury to the sciatic nerve results in difficulties with flexion of the leg, whereas weakness of hip extension may be caused by injury to the femoral nerve.
5. **e.** Robotic-assisted surgery has been associated with increased risk of positioning injuries. The use of steep Trendelenburg position may result in patient movement on the operating table, increased pressure on nerves and muscles, and elevated intraocular pressure. Prolonged operative time, obesity, and abduction of the arms have also been associated with increased risk of positioning injuries.
6. **d.** By side docking the robot, the legs can be placed supine rather than in stirrups, thus reducing the risk of calf compartment syndrome due to compression. While avoidance of Trendelenburg position would reduce the risk of positioning injury to the upper extremities, the procedure would not be feasible. Compression stockings and subcutaneous heparin reduce the risk of venous thromboembolic complications, but not compartment syndrome.
7. **e.** Of the listed factors, peritoneal closure and retention suture utilization have been theorized to reduce fascial dehiscence though the benefit of peritoneal closure is unclear. Mass closure has been demonstrated in multiple studies to have lower dehiscence rates than does layered closure. Use of nonabsorbable suture has not been associated with fascial dehiscence and is thought to be preferable to the use of rapidly absorbing sutures. Placement of sutures too close to the fascial edge risks tearing of the fascia, either upon tying the stitch or upon strain in the postoperative setting. This is the most common cause of dehiscence.
8. **c.** The organism most commonly found in wound infections is *Staphylococcus aureus*. Gram-negative organisms are less commonly found, but are frequently encountered in bowel and bladder surgery.
9. **d.** Hydrocelectomy, penile prosthesis, and inguinal lymph node dissection would all be considered "clean" procedures with low risk of infection upon proper observance of aseptic techniques. Both prostatectomy and cystectomy are considered "clean-contaminated" since a hollow viscus potentially harboring bacteria is opened during the case. Cystectomy with ileal conduit diversion carries the highest risk of infection given the exposure of the field to both urinary tract and bowel contents. Infectious risk would be greatest in the setting of excessive or gross fecal spillage.
10. **d.** Steep Trendelenburg position, commonly utilized in pelvic robotic-assisted laparoscopic procedures, is associated with increased peak airway pressure due to elevation of the diaphragm, increased intraocular pressure, and brachial plexus injury if shoulders and upper extremities are not supported. Vision loss has been reported as a result of ischemic optic neuropathy as a result of increased intraocular pressure, but hearing loss has not been directly linked.

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10 Management of Vascular Complications in Urology

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CHAPTER OUTLINE

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Instruments for Vascular Control and Repair
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Lumbar Vein Injuries
Inferior Vena Cava Tumor Thrombus
Chapter 10 Questions and Answers

KEY POINTS

1. Vascular injuries are a common type of major intraoperative complication in urology and occur in open, minimally invasive, and even endourologic procedures.
2. A thorough understanding of vascular anatomy and rigorous preoperative planning can minimize, though not entirely exclude, the possibility of an intraoperative vascular injury.
3. Even experienced surgeons encounter vascular complications, and, if unidentified or inadequately repaired, these injuries can have catastrophic consequences.
4. Following control of brisk bleeding, surgeons should pause to reorient themselves and reestablish situational awareness in order to prevent further complications.
5. Well-executed digital pressure can temporarily control nearly all sources of abdominal bleeding.
6. Vascular complications should be identified quickly and managed decisively, and surgeons should not hesitate to convert laparoscopic or robotic cases to open surgery upon injury to major vascular structures.
7. Repair should focus on ensuring tension-free repair and adequate luminal diameter and prevention of embolic and thrombotic complications.
8. Occlusion of the left renal vein does not cause venous hypertension due to collateral drainage, whereas occlusion of the right renal vein may result in venous hypertension, acute tubular necrosis, and renal insufficiency.
9. If not experienced in vascular surgical techniques, surgeons should consider intraoperative consult to vascular surgery or transfer to a tertiary care center if indicated.

Introduction

OVERVIEW

From open surgery to minimally invasive procedures and even endourology, vascular complications truly span the spectrum of urologic interventions and can result in significant short- and long-term morbidity and mortality. This chapter will discuss techniques and approaches to preventing, identifying, and managing intraoperative and postoperative vascular complications in urology and is intended to be a broad overview of the topic. While the chapter will reference laparoscopic, robotic, and endourologic concepts and injuries, the majority of this discussion will focus on traditional open surgical techniques, and the reader is directed to the respective chapters focusing on these other modalities for further information.

Representing 40% of all major intraoperative and postoperative laparoscopic urologic complications,[1] hemorrhage from vascular injury is the most common cause of morbidity and mortality in the perioperative period. While the exact nature of these injuries varies with the specific case and surgical approach, the incidence of hemorrhage requiring transfusion reported in the literature varies from 0.3%[2] for percutaneous nephrolithomy to 52% in one cohort undergoing radical retropubic prostatectomy.[3] As with any surgical procedure, complication rates vary with the nature of the procedure, patient comorbidities and anatomy, and surgeon experience. Interestingly, while intraoperative blood loss was strongly inversely correlated with surgeon experience, major vascular injuries appeared to occur with equal frequency in both novice and experienced surgeons.[4] This finding underscores the need for all surgeons, even those with significant experience, to follow key surgical principles such as careful tissue handling and meticulous dissection.

If a catastrophic vascular injury does indeed occur, surgeons must be willing to act decisively and take appropriate steps to control the bleeding and prevent exsanguination. Often, this includes rapid conversion of minimally invasive procedures to open surgery for direct control and subsequent repair of bleeding. Furthermore, these situations require clear and constant communication with the anesthesia team should it be necessary to implement aggressive resuscitation measures with intravenous fluids, blood products, and vasoactive medications. Even if the senior urologic surgeon is experienced in vascular repair, emergent intraoperative consultation to vascular surgery is often prudent and warranted. Finally, if the surgeon is practicing in a clinical setting where extensive resources including ICU critical care medicine are unavailable, damage control surgery (e.g., rapid identification and temporization of bleeding, abdominal packing, and temporary abdominal closure) and emergent transfer to a tertiary care referral center may be warranted.

Instruments and Supplies

Vascular surgery is a technically demanding surgical discipline requiring numerous surgical supplies in order to be performed correctly. While the entire gamut of instruments and supplies may not be available in an emergent setting, the surgeon should at a minimum have at his or her disposal a series of vascular instruments necessary for dissection, vascular control, and anastomotic repair.

INSTRUMENTS FOR DISSECTION

Dissection, particularly when conducted in close proximity to major vessels, is conducted bluntly using right angle clamps and/or sharply using vascular forceps with Metzenbaum or Church scissors. Vascular forceps are critical for active manipulation of vessels and surrounding tissue. These typically have small rows of interlocking serrations capable of atraumatically grasping even thin-walled veins if used appropriately. Right angle forceps provide a useful tool to encircle vessels and dissect a window for vessel loop or vascular clamp placement. Initial superficial dissection and/or rapid dissection away from critical structures can often be conducted using electrosurgical instruments. While traditional hemostatic surgical instruments such as electrocautery are still indispensable, newer devices that apply bipolar current (Ligasure, Covidien, Dublin, Ireland) or ultrasonic energy (Harmonic scalpel, Ethicon, Somerville, NJ) can also be used to rapidly dissect with good hemostasis. Caution must be used, however, as these devices are capable of significant vascular injury if used carelessly or inappropriately.[5,6] Finally, next-generation devices that use radiofrequency (Aquamantys, Medtronic, Dublin, Ireland) or argon gas (ABC system, Conmed, Utica, NY) show promise in providing superficial hemostasis. It must be noted, however, that none of these devices are capable of controlling hemorrhage from a major blood vessel, and use of these devices in the setting of uncontrolled hemorrhage, while tempting, will likely worsen the injury and exacerbate the problem.

INSTRUMENTS FOR VASCULAR CONTROL AND REPAIR

Vessel loops are brightly colored Silastic loops that can be placed proximally and distally and assist in rapid identification and, if necessary, atraumatic temporary occlusion of the vascular structure of interest until an appropriate vascular clamp can be applied. Vascular clamps are available in a wide variety of shapes and sizes for various applications and are designed to occlude vessel flow without traumatizing the vessel walls. These clamps can be categorized by their intended functionality; fully occlusive transverse clamps (Fogarty, Debakey, Wylie, Henly, etc.) are intended to occlude the entire vessel lumen, whereas partially occlusive side-biting clamps (Satinsky, Cooley, Lemole-Strong, etc.) are used to preserve partial flow while excluding a region of damage for repair. Bulldog clamps can also be useful in some settings, particularly where small vessels are involved and must be temporarily occluded. Potts scissors and aortic punches can then be used to create, modify, and/or prepare an arteriotomy or venotomy for subsequent repair. Needle holders are then used to grasp the appropriate suture/needle and conduct the repair. While the specific needle drivers used (Castroviejo, Jacobson, Cohan, etc.) vary widely according to surgeon preference, at a minimum they must be able to accurately control small-caliber

sutures and place the needle accurately in the intended tissue.

The suture used for vascular repairs is typically nonresorbable to provide adequate tensile strength until the vessel heals. One exception to this rule is in pediatric applications, where a slowly absorbable suture such as PDS (polydioxanone) can be used to facilitate future growth at the anastomotic site. Most commonly, these sutures are monofilament and composed of polypropylene (Prolene, Ethicon Inc, Somerville, NJ; Surgipro, Covidien Inc, Dublin, Ireland) or polytetrafluoroethylene (GORE-TEX, Newark, DE). Suture size varies with the specific application, but typically 2-0 to 3-0 suture is chosen for aortic reconstructions, 5-0 is used for renal and iliac repair, and 7-0 is appropriate for small vessel work. Sutures are usually double-armed with a tapered needle swaged at both ends of a continuous suture to allow for continuous suturing bidirectionally from the apex of the defect toward the opposite apex, where they can be tied to each other.

ENDOVASCULAR INSTRUMENTS

The Fogarty thromboembolectomy catheter is a key device with several useful features and applications in vascular surgery. Briefly, these catheters consist of a long catheter with a distal balloon that can be inflated and deflated manually to the proper diameter corresponding to the vessel of interest. In the setting of uncontrolled bleeding, these catheters can be placed directly into a bleeding vessel and inflated to the proper size to occlude the vessel until a more permanent solution can be employed. Standard Fogarty catheters range in size from 2F to 10F; for example, a 5F balloon is appropriate for iliac vessels. Following anastomosis, these catheters can also be used to remove any distal thrombus or emboli that may be present. To accomplish this, the catheter is inserted to a point far proximal or distal to possible thrombus, inflated with saline (or air for 2F balloons), and slowly withdrawn to expel the vessel contents into the operative field. Care must be taken to avoid overpressurizing the balloon, however, and causing endothelial damage and further thrombosis.

It is also worth mentioning that Fogarty occlusion catheters are also available for situations where endovascular occlusion is necessary. These catheters are available in balloon diameters ranging from 5 mm to 45 mm. If used properly, these catheters are capable of temporarily occluding nearly any vessel (including the abdominal aorta) to facilitate diminished blood loss and subsequent vascular repair in a bloodless field.

HEMOSTATIC AGENTS

A number of hemostatic agents are now available for rapid hemostasis in the setting of diffuse and/or uncontrolled bleeding (Table 10.1). Gelatin-based (Gelfoam, Pfizer, New York, NY), oxidized cellulose-based products (Surgicel, Ethicon, Somerville, NJ), and polysaccharide spheres (Arista, Bard Davol, Warwick, RI) all provide a physical matrix for clot formation to occur, but each has potential drawbacks (e.g. gelatin can swell and cause tissue compression, polysaccharide spheres also swell and are relatively contraindicated in diabetics, and cellulose can cause localized tissue acidosis). Other agents such as thrombin (Evithrom, Ethicon) and fibrin (Tisseel, Baxter, Deerfield, IL; Evicel, Ethicon) achieve hemostasis via active participation in coagulation and may be useful in controlling venous or even small arterial bleeding vessels or in damage control settings. Newer products derived from chitin and chitosan (HemCon Patch, HemCon, Portland, OR) have now recently become available, though data on effectiveness remain limited. Unfortunately, none of these products are able to stem blood loss from a significant defect in a major artery. If more extensive bleeding is present, surgical clips, including titanium clips and/or Weck polymer clips (Teleflex, Limerick, PA), are often used to control small- to medium-sized vessels rapidly if the vessel can be visualized and accessed. These clips can subsequently be removed if necessary to allow for a more definitive repair. Studies have shown that both of these solutions offer satisfactory hemostasis, even on larger vessels such as the renal artery.[7] It should be noted, however, that the use of Weck or Hem-o-lok clips is contraindicated in living donor nephrectomy because three deaths occurred from clip displacement and hemorrhage.[8]

Causes and Prevention of Vascular Injuries

CAUSES OF VASCULAR COMPLICATIONS

Surgical errors can occur preoperatively, intraoperatively, and postoperatively and can have devastating consequences on patient morbidity and/or mortality. While previous studies have invoked numerous specific causes for surgical errors including excessive workload,[9] sleep deprivation,[10] and poor communication,[11] most intraoperative vascular complications can be fundamentally categorized within three domains (Fig. 10.1): (1) technical errors, (2) cognitive factors, and (3) biologic characteristics. Within this framework, technical errors are most common[12] and encompass incidents such as inadequate tissue dissection and exposure leading to inadvertent vessel damage,

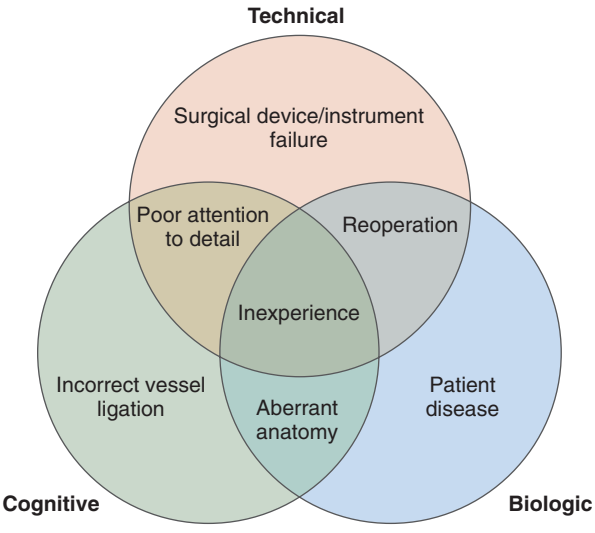


Figure 10.1 Domains of surgical error causes with examples listed within each category.

Table 10.1 Comparison of Commercially Available Hemostatic Agents Grouped by Category, With Advantages and Disadvantages Listed for Each

Category	Name	Description	Examples	Advantages	Disadvantages
Passive Mechanical Agents	Gelatin	Highly absorbent purified porcine hydrocolloid	Gelfoam Surgifoam	Low cost, off-the-shelf, room temperature storage Easy to work with and pliable	Can swell extensively and cause neighboring tissue damage, cannot be used for skin closure
	Oxidized regenerated cellulose	Dry absorbable alpha-cellulose mesh causing platelet adhesion and intrinsic pathway activation, low pH causing vasoconstrction	Surgicel	Can be rolled, cut, and manipulated Can be applied to anastamoses or organ surfaces Bactericidal (low pH)	Can swell extensively and cause neighboring tissue damage, can impair bone healing
	Collagen	Scaffold for clot formation and platelet activator	Ativene	Numerous formulations (sheets, powder, sponge, etc.) Rapid, easy to use Stored at room temperature	Cannot be used in blood scavenging systems (risk for DIC), cannot be used for skin closure
	Microporous polysaccharide spheres	Potato starch-derived, acts to remove water and concentrate platelets/proteins	Arista	Low cost, no preparation needed No increased risk for infection or foreign body reaction Rapid absorption (48 hr)	High sugar content; use with caution in diabetic patients
Active Biologic Agents	Thrombin	Converts fibrinogen to fibrin, directly catalyzing coagulation	FloSeal	Liquid application No inhibition by urine Can be used on arterial bleeding	Expensive, requires mixing
	Fibrin	Fibrinogen/factor XII and thrombin/calcium solutions that, when mixed, form fibrin clot	Tisseel, Evicel	Can be used on arterial bleeding No mixing required Rapid hemostasis	Must be thawed and mixed prior to use, risk of immune reactions
Other Agents	Chitosan-based	Natural polymer causes erythrocyte aggregation and platelet activation	HemCon	Rapid deployment, room temperature storage	Contraindicated in patients with shellfish allergies
	Cyanoacrylate-based	Free radical polymerization	Dermabond	Rapid exterior hemostasis (e.g. skin closure)	Cannot be used on mucosal surfaces
	Glutaraldehyde-based	Glutaraldehyde cross links albumin to wound	BioGlue	Can be used on moderate arterial bleeding	Expensive, possibly mutagenic, hypersensitivity reactions
	PEG-based	Polyethylene glycol polymerization	Coseal	Fast-acting	Can swell extensively and cause neighboring tissue damage
	Tranexamic acid	Synthatic lysine analog that blocks plasminogen and fibrinolysis	Cyklokapron (TXA)	IV administration (can be used postoperatively)	Ocular side effects, rare cases of anaphylaxis

instrument failure causing hemorrhage (e.g., endovascular stapler malfunction[13]), or careless/aggressive dissection causing traumatic injuries to fragile structures. Isolated biologic factors including aberrant anatomy and/or advanced disease processes can also deceive even the most cautious and experienced surgeons. For example, a recent case report described the development of significant scrotal edema following left living donor nephrectomy and large gonadal vein ligation in a patient with a known duplicated infrarenal inferior vena cava.[14] Bridging the domains of biologic and technical causes, patient characteristics such as morbid obesity or prior abdominal surgeries can make an otherwise straightforward case far more complicated. Gabr et al. showed that morbid obesity was associated with a 21-fold greater likelihood of conversion from laparoscopic to open radical nephrectomy,[15] and a recent study by Seifman and colleagues demonstrated that abdominal operations in patients with a prior abdominal surgical history were associated with longer mean hospital stay and higher rate of complications but surprisingly no difference in mean operative time.[16]

Perhaps the most insidious of these potential sources of complications is the cognitive domain and what can be best described as lapses in clinical judgment. These are likely the most difficult to accurately identify and minimize because of human nature and the difficulty in introspectively identifying and acknowledging these as a surgeon. Data from malpractice claims for surgical errors in Belgium showed that 57% of lawsuits with medical mistakes were directly attributable to errors in judgment.[12] These errors can be clustered as oversights in situational awareness and/or poor decision making.[17]

Central to all three of these domains, however, is surgeon experience. A recent case series of robotic-assisted radical cystectomies with intracorporeal neobladder highlighted the importance of experience in minimizing operative time and complication rate. The study showed that as the surgeons became more familiar with the operation over their

first 67 cases, operative time dropped by nearly 40%, conversion to open surgery dropped by 30%, and complications fell by 40%.[18] These data underscore the ability of experience to potentially mitigate some of the risk associated with aberrant biology and/or difficult judgment calls based upon limited information.

Types of Vascular Injuries

From minor puncture wounds to complete transection of the aorta,[19] iatrogenic vascular injuries in urologic surgery occur in both arteries and veins and truly span the gamut of morbidity. Injuries can occur from a variety of traditional open surgical instruments (scalpels, dissecting scissors, forceps, electrocautery, staplers[13,20]), minimally invasive surgical instruments (Veress needles,[21–23] trochars,[24] needle carriers[25]), and even endoscopic instruments (ureteroscopes[26,27] and JJ ureteral stents[28]). These instruments can be responsible for injuries of various types, including punctures, lacerations, transections, and avulsions. Punctures occur particularly frequently during laparoscopic or robotic port placement (e.g., Veress needle puncture of the iliac artery[21]) and vary in severity from small-caliber needle puncture wounds to the epigastric vessels to trochar injuries to the aorta[25,29–31] and/or IVC[32] that require immediate conversion via laparotomy. Lacerations[33] represent perhaps the most common form of vessel injury during the dissection phase of the operation and typically occur from sharp dissection with dissecting scissors or more commonly with electrocautery. These injuries can commonly be repaired primarily. Transection injuries,[34] on the other hand, are typically more severe and require more extensive repair. Avulsion injuries[35] can represent possibly the most complex injuries to repair, as they most commonly involve a major venous structure (e.g., lumbar vein to IVC) and require extensive mobilization of poorly visualized structures and considerable skill to repair.

Identification of Vascular Injuries

The rapid identification of iatrogenic vascular complications is critical to minimize blood loss and ensure the best possible outcomes for patients who suffer an arterial or venous insult. In many cases the presence of a vascular injury is self-evident. The acute loss of surgical field visualization due to the rapid accumulation of blood and/or the visual identification of blood spraying from a vessel wall defect are obvious signs of the presence of a problem. In other cases, however, the findings can be subtle and include the presence of a pulsatile hematoma (particularly in the retroperitoneal space) or the gradual distention of the abdomen in the postoperative period. While these findings may appear to be less pronounced or dramatic, the consequences of missing such a sign are every bit as severe. Nausea and vomiting may also be present. Finally, intraoperative or postoperative bleeding can often also be identified via changes in vital signs and hemodynamic instability. Classically, the first signs of hypovolemic shock are isolated tachycardia, anxiety, and low urine output,[36] but caution must be taken when interpreting data based solely upon the presence or absence of these findings, as a significant proportion of surgical patients will be on pharmacologica agents such as beta-blockers and may not have the capability to mount an appropriate physiologic response to biologic stress. If left unchecked, ongoing volume losses will eventually lead to hypotension, signs of end-organ dysfunction, and circulatory collapse.

If the rate of bleeding is less catastrophic, then the only evidence for ongoing losses may be a gentle drift in the hemoglobin and hematocrit on daily labs. This can often be difficult to interpret in the setting of significant postoperative fluid shifts and crystalloid resuscitation, and a high index of suspicion is often necessary. Imaging studies may also play a role if ordered in a timely fashion. Plain film examination of the abdomen has little role in the diagnosis of acute bleeding, but cross-sectional imaging can sometimes aid in the identification and location of bleeding.

Initial Management of Bleeding

Upon identification of rapid intraoperative bleeding, the surgeon should attempt to rapidly identify the source of bleeding while simultaneously minimizing blood loss and achieving relative hemostasis (Fig. 10.2). If the damaged vessel is small and clearly visualized, then electrocautery may be a viable first choice. If the bleeding is more substantial and visualization becomes impaired, the surgeon should consider adding a second suction device for visualization purposes while simultaneously continuing to work to control the bleeding. In some situations the source of bleeding is not easily appreciated and the rate of blood loss is not immediately life threatening; these circumstances may favor aggressive wound packing with sponges to allow for the coagulation process to stem the bleeding in time. When successful, the removal of these sponges will demonstrate a dramatic improvement (or even cessation) of bleeding, and the damage can then be definitively repaired if necessary.

If the vessel is large, however, and the source of bleeding has not been well dissected, then the use of the Bovie is likely to obfuscate the tissue planes/structures, cause further vessel damage, and ultimately make subsequent repairs far more difficult. A better option in these circumstances is to apply direct pressure to slow the bleeding. In open surgery, this is best accomplished using digital pressure for a variety of reasons. First, the use of a finger or hand to stem the bleeding is rapid and does not require any specialized equipment to be passed into the operating field. Second, the technique is easy and intuitive to all surgeons, and it is unlikely that further damage will occur even with vigorous pressure. This approach also provides instantaneous tactile feedback, which may assist in identifying a pulsating vessel in tissue that is not yet clearly visualized. If an attentive assistant surgeon performs this maneuver, then the primary surgeon can also continue to dissect and expose the surrounding tissue in a relatively bloodless field. It is important to note, however, that while this technique can often slow the bleeding dramatically, rarely will it result in perfect hemostasis; often secondary maneuvers are needed to more definitively control the bleeding.

If the vessel has been previously identified and a vessel loop has been applied, then hemostasis is rapidly achieved

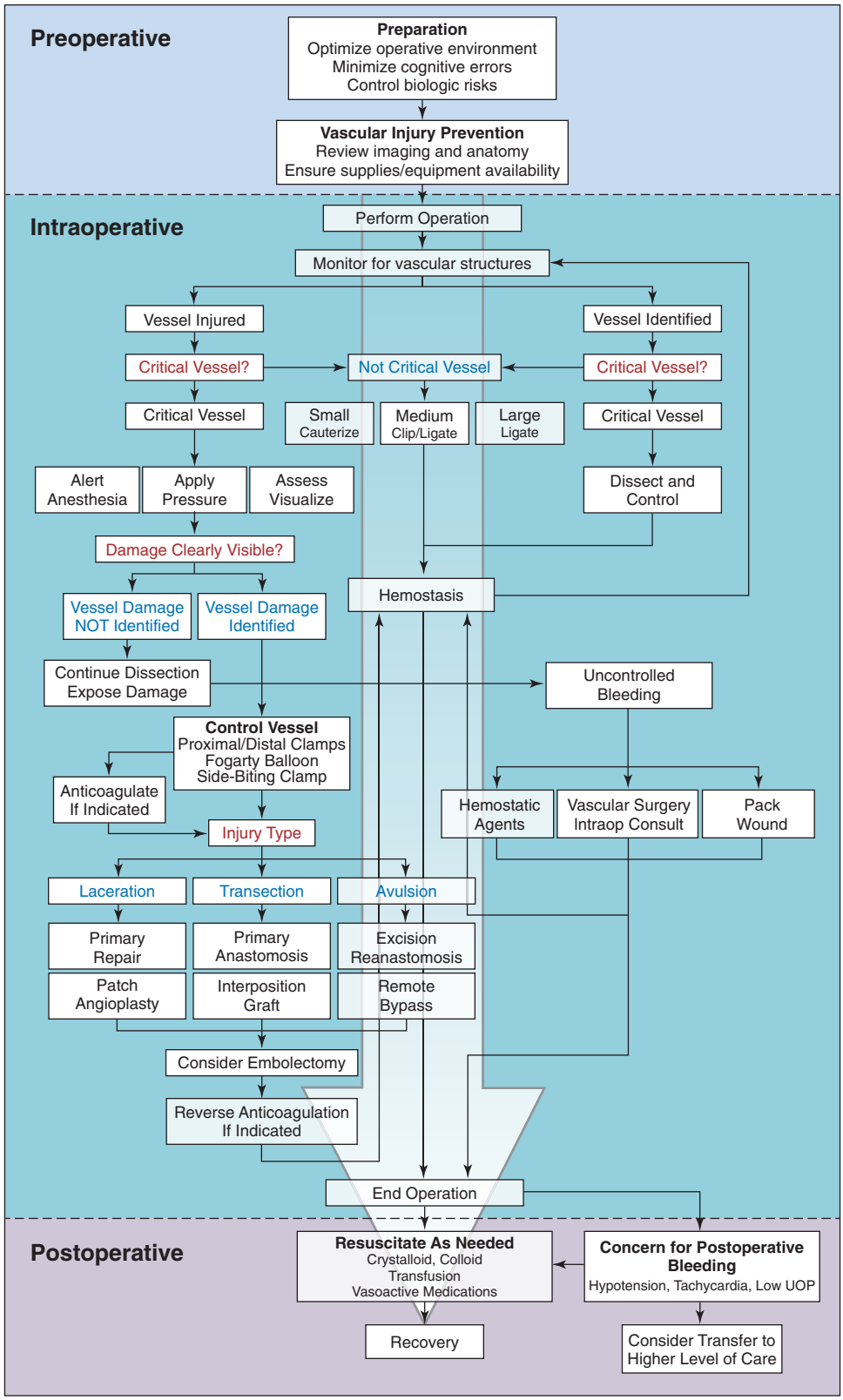


Figure 10.2 Flow chart demonstrating representative management approach to intraoperative hemorrhage. Note decision points highlighted in red.

by cinching the loop. If the vessel has been fully transected, however, this technique runs the risk of allowing the vessel loop to slip off (sometimes unexpectedly). On the other hand, if the vessel is clearly identifiable and the surrounding anatomy is well defined, then a vascular clamp can often be applied to the proximal aspect of the vessel. It is tempting to attempt to clamp in suboptimal conditions; however, the blind application of these instruments can often result in additional damage and worsening hemorrhage. An alternative approach that may be useful includes the placement of an occlusive Fogarty catheter proximal to the defect; this technique can be used as a temporizing measure while further dissection is completed in anticipation of clamp placement. In the hands of an experienced surgeon, this approach may also be used while the repair is completed, with removal of the catheter just prior to final closure and suture tying.

If bleeding is encountered in laparoscopic or robotic surgeries, similar fundamental principles still apply but key differences also exist. The primary difference is that poor visualization can rapidly compound the problem if action is not immediately taken. The first step is to apply direct pressure to the damage with an appropriate laparoscopic instrument (a sponge stick or blunt tip suction works well) to slow the bleeding. Simultaneously the pneumoperitoneum should be increased to help tamponade the bleeding, particularly if venous in nature. Additional access ports can then be rapidly placed to assist in suctioning, retraction, or suture passing. It must be noted, however, that controlling and subsequently fixing the bleeding vessel laparoscopically is often very difficult, and the prudent surgeon must quickly give serious consideration to decisive conversion to traditional open surgery. While laparoscopic management may be feasible for injuries to smaller vessels, any injury to the major vessels (aorta, IVC, iliac vessels, renal vessels, etc.) warrants immediate conversion, and even smaller injuries that are unable to be controlled quickly should be addressed via laparotomy. If the decision is made to open, then the presence of a midline port can be useful. By angling the port upward and placing it against the abdominal wall, the abdomen can be sharply entered over the port without concern for bowel injury.

Postoperatively, bleeding patients should be given aggressive fluid resuscitation and blood products as needed (Fig. 10.2). Numerous studies have now demonstrated noninferiority in restrictive blood product transfusion strategies in patients undergoing abdominal surgery.[37,38] Emerging data from the trauma literature also support transfusion with a 1:1:1 ratio (plasma: platelets: red blood cells),[39] though this finding has not yet been replicated in the perioperative hemorrhage setting. Transfer to the ICU may be warranted if the bleeding is brisk and there is concern for shock. If the patient becomes unstable or persistently bleeds, then operative exploration is indicated.

Definitive Operative Management of Vascular Injuries

ANTICOAGULATION

Following initial control of bleeding, definitive management of the injured vessel is critical to ensure re-bleeding does not occur. Prior to performing the vascular repair, the surgeon should confirm that adequate tissue dissection and mobilization has been completed. The surgeon should then determine the need for systemic anticoagulation and/or proximal and distal embolectomy. If efforts to restore flow will require greater than ~30 minutes, then the risk of thrombus formation increases and further efforts must be undertaken to prevent thrombosis and/or embolization. Unless contraindicated (e.g., prior episode of heparin-induced thrombocytopenia), heparin is the agent of choice for systemic anticoagulation. Heparin is a naturally occurring glycosaminoglycan that binds to and activates antithrombin III, which subsequently inactivates thrombin and factor Xa and prevents clot propagation. Heparin activity onset occurs within 1 minute of administration,[40] and heparin clearance occurs through both rapid saturatable mechanisms (e.g., depolymerization) and slower first-order mechanisms (e.g., renal clearance);[41] practically, this means that the half-life varies from 30 minutes for small IV boluses (25 U/kg) to 150 minutes for larger doses (400 U/kg).[42] Heparin dosing can be titrated intraoperatively by frequent measurements of the activated clotting time (ACT) via point-of-care testing. Once the repair is completed, heparin can be rapidly reversed by administration of protamine sulfate, a cation that directly binds to and inactivates the anion heparin. Protamine should be administered at 1 milligram protamine to 100 IU heparin and should be given first as a test dose to assess for anaphylactoid reactions. Of note is that giving excessive protamine has been shown to paradoxically cause a hypocoagulable state.[43]

EMBOLECTOMY

In addition to systemic anticoagulation, serious consideration should be given to arterial or venous embolectomy in situations where the definitive repair takes a significant amount of time (more than 30 minutes) and there is concern for thrombus formation. Failure to do so can result in flow impairment, clot propagation, and distal embolization causing ischemia. In order to perform proximal and distal embolectomy, a Fogarty catheter is inserted and advanced with the balloon deflated. The balloon is then inflated and the catheter withdrawn while using tactile feedback to maintain proper balloon tension on the vessel wall. The maneuver should be repeated until no further clot is obtained. Care must be taken not to denude the endothelium, which can exacerbate the situation and worsen the thrombosis.

GENERAL PRINCIPLES OF VASCULAR REPAIR

In general, vascular repair is considered one of the most technically challenging aspects of any surgery. The construction of a watertight tension-free anastomosis without luminal narrowing requires both knowledge and proper technique to perform correctly. When suturing vessels, the needle should be placed directly perpendicular to the vessel wall and across all layers of the vessel to minimize risk of pseudoaneurysm formation. This is particularly important in the setting of a possible intimal flap, which if left uncontrolled can result in occlusion and thrombosis of the vessel. Sutures should typically be placed at 1-mm intervals and with 1 mm of tissue purchase. If the vessel

is atherosclerotic, the placement of these sutures can be challenging and will ultimately be dictated by the location that most easily allows the needle to pass. If the vessel is small in diameter (<4 mm), then the vessel ends should be spatulated on opposite sides and anastomosed to prevent anastomotic narrowing.

APPROACHES TO DEFINITIVE REPAIR

Numerous repair or ligation techniques are available to surgeons depending on the nature and location of the injury. In most cases of venous injury, the vessel can simply be ligated and the venous drainage allowed to collateralize as needed. If, however, the injury is arterial in nature, then the surgeon must assess whether permanent ligation will result in ischemia of any critical tissues being perfused by the artery. If adequate collateral flow is present (e.g., in the pelvis) or the artery is small (<2 mm), then vessel ligation is the quickest and simplest approach. This can be accomplished using surgical clips, Hem-o-lok clips, a vascular stapler, or silk ligatures (2-0 or 3-0). The area can then be inspected for hemostasis and the operation continued. If the vessel is critical to end-tissue perfusion and the vessel is larger (>2 mm), then the defect should be repaired and blood flow restored.

Primary repair is often the most straightforward approach if the defect is small and the surrounding vessel wall tissue remains uncompromised. These repairs can be performed using running or interrupted suture of the appropriate size, and care must be taken not to narrow the lumen, which predisposes the vessel to further stenosis and thrombosis.

If primary repair is not feasible due to the size or complexity of the lesion, then onlay patch repair (patch angioplasty) is warranted. This technique is also indicated if primary closure of the defect would result in significant stenosis to the vessel. While data from iatrogenic injuries remain limited, a Cochrane review meta-analysis of data from the carotid endarterectomy literature suggests that, at least in the isolated setting of controlled arteriotomy, patch closure is far superior to primary closure with regard to stenosis rate, thrombosis, and stroke.[44] The choice of patch material seems to be less critical than the decision itself to patch, and several options are routinely used.

Broadly speaking, these patch material choices can be categorized as biologic or synthetic. Biologic options include autologous vein, bovine pericardium,[45] or parietal peritoneum,[46] while synthetic alternatives include Dacron and Teflon grafts. Dacron is a polyester-based graft composed of polyethylene terephthalate. Modern grafts are either woven or knitted; woven grafts are stronger but less compliant, while knitted grafts are also widely used and often treated with collagen, gelatin, or albumin. Teflon or PTFE (polytetrafluoroethylene) grafts are also commonly used. There appears to be no strong data to support the use of autologous tissue (saphenous vein), synthetic (Dacron), cadaveric (bovine pericardium), or peritoneal peritoneum for vessel patches, and the decision seems entirely dependent on surgeon preference and access to these various options.

In some cases, the damage to the vessel is too severe or geometrically unsuitable for primary repair or patch repair; in these circumstances an excision and reanastomosis is often indicated. This approach, however, often requires further dissection either proximally or distally (or both) in order to mobilize adequate vessel length to ensure a tension-free anastomosis. If this approach appears to impart significant tension on the repair, then an interposition graft should be used. The material selection of this graft follows similar principles to patch repair as described above.

If open repair is not feasible or fails, then alternative approaches, including endovascular repair, should be considered. Two case reports from the literature describe patients with prior ureteroileal diversion complicated by strictures and treated with cutting balloon endoureterotomy complicated by common iliac artery damage and massive hemorrhage.[26,47] Both cases were successfully treated with endovascular stent repair of the damage. Aortoureteric fistulas also appear to be amenable to endovascular management in select circumstances. A recent case series identified 20 ureteroarterial fistulas, 74% of which were associated with pelvic radiation and 84% of which occurred in the setting of chronic indwelling ureteral stents. While endovascular repair appeared to confer similar morbidity when compared to open surgical repair, the overall mortality still approached 50%.[48] Further tempering enthusiasm for this approach is the concern for placement of a foreign body (e.g., covered stent) in a contaminated space in direct contact with urine. While the initial intervention may stem blood loss and temporarily alleviate concerns over exsanguination, there exists a long-term risk for graft infection and recurrent bacteremia/sepsis. In this setting, it may be prudent to consider acute endovascular stent placement followed by definitive open surgical management including stent graft removal at a later date when the patient is more stable.

Complications of Vascular Injuries

PELVIC/RETROPERITONEAL HEMATOMA

Hematomas represent either a prior hemorrhage that is now hemostatic via physiologic hemostatic mechanisms, or – in the case of a rapidly expanding hematoma – uncontrolled ongoing bleeding. If the hematoma occurs in a hemodynamically stable patient, then observation is possible. If, however, the hematoma is large, rapidly expanding and pulsatile, associated with hemodynamic instability, and/or located in an anatomic location capable of containing enough bleeding to cause exsanguination, then further intervention is usually warranted. In the setting of urology, the most common location for this life-threatening bleeding is in the pelvis (particularly in trauma) or in the retroperitoneum (e.g., with renal surgery). In both of these spaces, extrinsic compression (traditionally the first maneuver with a hematoma) is not possible. In these cases, endovascular management via interventional radiology and embolization is commonly performed. If this fails or the patient is extremely unstable, then surgical exploration is indicated.

THROMBOSIS AND EMBOLIZATION

Given adequate disturbance to Virchow's triad of hypercoagulability, endothelial damage, and stasis, any vessel in the

body can and will thrombose. This is most clinically relevant within urology in procedures requiring significant involvement or manipulation of major vascular structures (e.g., renal arteries, vena cava, aorta, iliac arteries, etc.). Thrombosis can occur due to excessive vessel manipulation causing endothelial denudation, stasis from decreased or absent flow while a repair is being completed, and/or hypercoagulability from lack of adequate anticoagulation.

As with all intravascular thrombosis, the acute consequences of arterial or venous compromise depend both upon the degree to which flow is impaired and upon the tissue that is both upstream and downstream of the lesion. Of the two, arterial thrombosis is the more acutely concerning entity and can rapidly cause downstream ischemia and necrosis if inadequate collateral flow is present. Venous thrombosis, on the other hand, is usually less immediately concerning because of the distributed nature of venous drainage and the presence of collaterals, which can dilate to accommodate increased flow. The converse is true for subacute or chronic thrombosis. If the downstream tissue survives the initial insult, arterial thrombosis will often resolve spontaneously with adequate collateralization and without long-term sequelae. If, however, a venous thrombosis is allowed to propagate, then the risk for distant embolic events (e.g., pulmonary embolus) increases. Most of these complications (both acute and chronic) can be prevented with intraoperative attention to detail and appropriate interventions such as Fogarty embolectomy and/or heparinization. Furthermore, fastidious postoperative care, including prevention of deep venous thrombosis, is critical to ensuring optimal outcomes and minimizing rates of pulmonary emboli.

Arteriovenous Fistula

Iatrogenic arteriovenous fistula (AVF) formation represents an unexpected but potentially devastating complication from several routine urologic interventions, particularly with renal surgery. The literature describes several cohorts of patients undergoing partial or radical nephrectomy and the subsequent development of pseudoaneurysm with or without AVF.[49–51] The incidence of this complication has been reported to be as high as 2.7%.[52] It appears that en bloc stapling of the renal hilum may represent a risk factor for the development of a renal hilar AVF.[53] Less commonly, these have also been reported for endourologic procedures such as laser lithotripsy.[54] Finally, spontaneous fistulas can occur rarely and present in bizarre and unexpected ways, with case reports describing the development of a large varicocele from abdominal aortic aneurysm causing aorto-renal vein fistula[55,56] or pudendal artery-pampiniform plexus AVF.[57] Regardless of the etiology, the majority of AVFs are treated using endovascular selective embolization.

Stenosis

Vascular stenosis can occur following intraoperative vascular repair and subsequent anastomotic narrowing, fibrosis, and intimal hyperplasia. The functional consequences of the stenosis can be understood using the Law of Pouiselle, which relates pressure across a vessel to length, flow, viscosity, and radius. Simplified, the law states that a flow across a stenosis is linearly inversely proportional to its length and directly proportional to the fourth power of the radius. In other words, a narrowing of 50% will result in a 16-fold reduction in flow. This relationship underscores the necessity to avoid luminal narrowing and employ patch angioplasty if there is any concern for significant luminal narrowing. Stenoses can be managed using endovascular approaches (balloon angioplasty, stenting),[58] or they can be operatively repaired at a later date.

Specific Cases of Vascular Injury

LAPAROSCOPIC ACCESS INJURIES

While both Veress and trocar injuries[22,24,30,32] (including during Hasson access[29,59]) have been reported during laparoscopic entry, it is now clear that Veress needle access carries a significantly higher rate of vascular injury[60] and must be undertaken with caution. A recent review article identified a 0–0.03% risk of vascular injury during open Hasson access and up to a 1.33% risk for the closed Veress approach,[60] but due to systematic bias associated with underreporting, it is likely that the true incidence is even higher. While there have been case reports describing laparoscopic and robotic repair of iliac[34,61,62] and aortic[63] injuries, we believe that these injuries warrant emergent open conversion and repair by all but the most experienced of minimally invasive surgeons.

ARTERIAL INJURIES

Aortic Injuries

Injuries to the aorta represent perhaps the most catastrophic of all iatrogenic vascular injuries. Aortic trauma most commonly occurs during initial access for laparoscopic cases,[22,24,29] during dissection for open surgical cases,[64] and as a result of less common urologic situations. The aorta is particularly vulnerable during retroperitoneal dissections such as nephrectomy or partial nephrectomy[65] or retroperitoneal lymph node dissection.[66] In many cases the injury occurs because of disease adherence to the aortic adventitia, and preoperative imaging can guide intraoperative management. Care must be taken to develop the proper peri-aortic plane during dissection, as patients who have previously received chemotherapy or other neoadjuvant therapy are prone to weakened tissue layers and the subadventitial plane can inadvertently be dissected, resulting in a weakened aortic wall and increased risk for future hemorrhage. In some cases management may even require vascular surgery coordination and aortic replacement.

In the majority of cases these injuries can be identified and repaired intraoperatively, though exsanguination remains a serious risk. Once encountered and identified, it may be tempting to explore and cross-clamp the suprarenal aorta as a first-line maneuver. This approach, however, carries the risk of further damage to the diaphragmatic crura and the neural and lymphatic network overlying the aorta at this location. Instead, the surgeon should attempt to access the supraceliac or distal thoracic aorta by retracting the stomach caudally and the left lateral segment of the liver to the right, exposing the lesser omentum and allowing digital compression of the aorta

until the bleeding can be controlled elsewhere. In addition to those injuries identified and repaired immediately, there are at least two case reports of intraoperative aortic insult that was not identified immediately and required reoperation.[19,30] In both cases the patient underwent nephrectomy (one for nephrolithiasis and the other for Wilms' tumor) complicated by immediate postoperative lower limb numbness and pulselessness. In both cases the patient was explored and found to have a ligated infrarenal aorta, which was repaired with a synthetic interposition graft. Both patients experienced partial recovery of sensory and motor function, and neither required amputation. While operative details for these cases are scant, it appears that brisk bleeding impairing surgeon situational awareness and inducing panic and/or desperation to control bleeding caused the injuries. It is paramount in these stressful situations to control the bleeding, stop, and reorient with regard to anatomy and patient status before completing the operation and leaving the operating room.

In addition to traditional intraoperative complications, the urology literature contains several other references to unusual cases involving the aorta and the upper tract. Vagnoni and colleagues described the case of a patient who underwent pelvic surgery complicated by ureteral injury and subsequent reanastomosis who presented with massive hematuria later found to be secondary to ruptured aortic pseudoaneurysm requiring operative repair.[67] Other reports describe the formation of aorto-ureteric fistula causing massive hematuria.[68] Finally, another report describes the development of an abdominal aortic aneurysm after BCG treatment for bladder cancer; further workup revealed the presence of *Mycobacterium bovis* within the excised tissue.[69] Taken together, these case reports suggest that urologists should have a high index of suspicion for a variety of vascular complications, both common and uncommon, when patients present with significant hematuria and/or abdominal pain in the absence of obvious explanation.

Visceral Artery Injuries

Numerous case reports now exist describing injury to the visceral arteries during urologic surgery. Injury to the superior mesenteric artery (SMA) during renal or adrenal surgery is the most common scenario,[70–73] but case reports have also identified celiac compromise.[72,73] Most reports identify distorted anatomic relationships due to heavy tumor burden as the primary causative factor. This disease burden can often malrotate or translate the renal hilum in unexpected ways. Extreme care must be taken when evaluating the preoperative imaging studies to help identify cases at risk for these complications, and intraoperatively the surgeon must have a high index of suspicion for aberrant anatomy. In our practice, we employ a threefold strategy to ensure that the SMA is not inadvertently ligated. We first critically assess whether the vessel in question is located laterally on the aorta and behind the renal vein (except in the case of a retroaortic vein), and we dissect the vessel out more clearly if there is any doubt. This is particularly difficult, however, if the patient is in the right lateral decubitus position and/or when there is a large left-sided mass being resected. Due to this, we then proceed to atraumatically occlude the artery of interest via vessel loop and assess for changes in the turgor and appearance of the kidney that may suggest blanching. Finally (and most importantly) we palpate the mesenteric arcade to confirm adequate pulsations remain. Following vessel transection, upon completion of the case we always run the bowel and assess for any signs of ischemia. If these maneuvers fail to elucidate the nature of the vessel in question, then it is also possible to approach the hilum from the posterior aspect of the kidney and to palpate the vessels individually prior to ligation. Once identified, repair of the visceral vessels should be undertaken without delay to avoid prolonged ischemia. Vascular repair can be conducted via direct reanastomosis, placement of an interposition graft, aortic reimplantation, bypass via the splenic artery, or construction of a patch angioplasty. If these injuries are identified intraoperatively and promptly fixed, outcomes remain good. If the injury is missed, however, then extensive bowel and/or foregut ischemia and ultimately death will occur.

Thoracic and Lumbar Segmental Artery Injuries

Thoracic and lumbar arteries are paired posterior arteries associated with the thoracic and upper lumbar bodies. These arteries can be encountered during posterior dissections for lymph node dissection. It is important to keep the dissection far enough from the aorta that if transection does indeed occur, the artery stump can directly be controlled and ligated. If the dissection is carried directly adjacent to the aorta and there is no proximal stump available, then primary closure of the aorta is indicated. The critical maneuver in doing so is to mobilize the aorta adequately to permit satisfactory visualization when oversewing the defect.

Iliac Artery Injuries

Numerous case reports exist describing iatrogenic injury to the common or external iliac artery during urologic procedures. These can occur during minimally invasive pelvic procedures,[5,26,34] during renal transplantation,[58,74,75] or during other less common urologic situations (e.g., via needle carrier during vaginal sling placement[25]). It is important to note that the external iliac is the sole provider of blood flow to a significant region of the lower limb, and prompt repair of this vessel is critical to maintain perfusion and prevent ischemia and limb amputation. Repair can be conducted as previously described here (e.g., primary repair for small defects or reanastomosis for uncomplicated transections), but in this setting three other options are also available. First, if an interposition graft is deemed necessary, then the native hypogastric artery can be transected, the distal portion ligated, and the proximal component reanastomosed to the distal external iliac artery as an in situ interposition graft. Alternatively, the external iliac vein can also be harvested and placed in a reversed fashion as an interposition graft. Finally, if these options are deemed unsuitable or the defect is significant, then vascular surgery should be consulted intraoperatively to assess the suitability bypass using prosthetic conduits or extra-anatomic approaches (axillofemoral or femoral-femoral bypass).[76]

VENOUS INJURIES

Inferior Vena Cava Injuries

Brisk bleeding from the vena cava can be a truly frightening experience associated with rapid development of

hemodynamic instability and exsanguination if not quickly addressed. We employ a stepwise fashion to interventions to control vena caval bleeding. If the defect is small (e.g., avulsed lumbar vein), then digital pressure is satisfactory to minimize bleeding while arrangements are made for primary repair. An exclusion clamp (e.g., Satinsky) can then be placed to allow for venous return to recommence. Defects of this nature can usually be closed primarily with running nondegradable suture. If the defect is larger and digital pressure is insufficient, then the IVC can be controlled proximally and distally and further mobilized for more extensive repair. If the defect is large enough that primary closure would lead to significant luminal narrowing, then patch venoplasty should be undertaken with one of the patch types previously discussed in this chapter.

If the above maneuvers are unable to provide relative hemostasis, then more aggressive measures should be employed. Sequential Allis clamps can be cautiously placed to oppose the IVC walls across the defect and slow bleeding. Extreme care must be taken, however, when performing this maneuver, as the venous walls are fragile and can easily tear further and exacerbate the problem. If the above measures continue to fail and the defect is infrarenal, then IVC ligation has been described by several groups.[77,78] This maneuver is best tolerated in situations where gradual IVC occlusion has occurred prior to the operation (e.g., renal cell carcinoma with progressive tumor thrombus) and adequate collateralization has previously taken place. If a previously patent IVC must be ligated intraoperatively for massive hemorrhage, the incidence of deep venous thrombosis and distal venous congestion is extremely high, and preservation of the remaining venous collaterals should be prioritized. Suprarenal IVC ligation may also be considered in some cases where death would otherwise be imminent, but the surgeon must understand that kidneys without satisfactory venous outflow will likely be lost and hemodialysis may be necessary.

Renal Vein Injuries

Hemorrhage from the renal vein can result in rapid exsanguinating blood loss. Damage to the left renal vein is more forgiving because of the presence of venous collaterals (gonadal, adrenal, lumbar branches). In this setting, the left renal vein can be ligated with minimal concern for venous hypertension or nephron compromise. The right renal vein is particularly thin-walled and fragile and lacks this network of collateral drainage, and occasionally a posterior branch can be injured during circumferential dissection. If such an injury occurs, immediate digital pressure should be applied. If the injury occurs in the context of performing a radical nephrectomy, then the surgeon should attempt to control the renal artery first and then address the vein afterward. If this proves to be difficult, then a large vascular clamp can be placed across the entire hilum and the kidney removed. The edges of the artery and vein can then be identified and carefully oversewn. If the intended operation is renal-sparing in nature (e.g., partial nephrectomy), then the surgeon must work quickly to find an alternative solution. One option is to rapidly mobilize the entire kidney to facilitate posterolateral exposure of the vein for subsequent repair. Alternatively, in rare situations with appropriate expertise and resources, a renal autotransplant may be performed. It should be noted, however, that right renal vein transection – except in very rare circumstances – will result in excessive bleeding and will necessitate nephrectomy.

Hypogastric (Internal Iliac) Vein Injuries

Bleeding from injuries to the hypogastric veins can occur during renal transplantation or pelvic lymph node dissection. The number and location of these can vary slightly, and dissecting these branches can be challenging. We typically mobilize the common, external, and proximal internal iliac arteries and retract these medially. We then obtain circumferential control of the external and common iliac veins and encircle them with umbilical tape, which aids in upward traction and further dissection of the hypogastric branches. Alternatively, these branches can be approached and controlled from the lateral approach by retracting the psoas muscle laterally. Once identified, if necessary the hypogastric veins can be clipped or ligated and divided to allow full mobilization of the external iliac vein. If these branches are damaged and vascular control is lost and the vein retracts, then digital pressure can be applied and a slender clamp inserted and the vein wall grasped. The vessel can then be delivered into the operative field, twisted to stem the bleeding, and suture ligated.

Lumbar Vein Injuries

Lumbar veins can be particularly troublesome if damaged during IVC or retroperitoneal operations. In order to avoid damaging – or if necessary repair – these vessels, the IVC is gently lifted anteriorly via umbilical tape and any veins encountered are ligated and/or clipped. If the vessel is entirely transected and the posterior stump retracts into the surrounding tissue, then a similar technique as described for hypogastric control can be employed (e.g., grasp the vein well, gently retract, twist, and suture ligate). If this proves to be unsuccessful, then a hemostatic stitch can be applied directly to the posterior body wall musculature to control the bleeding.

INFERIOR VENA CAVA TUMOR THROMBUS

While not an iatrogenic vascular complication per se, renal cell carcinoma (RCC) with venous extension represents a unique biologic situation that may be initially encountered, though not necessarily treated, by many practicing urologists. Surgical management of this condition represents one of the most challenging conditions that urologists face, and a comprehensive team-oriented approach is necessary to achieve the best outcomes. Here we discuss the general principles surrounding diagnosis, prognosis, and management of IVC thrombus.

With an incidence of over 60,000 new cases annually, RCC is the third most common genitourinary malignancy in the United States and represents 3.7% of all new cancer diagnoses each year.[79] It is also the most lethal form of genitourinary cancer, with an estimated 14,000 deaths annually. RCC is unique in its affinity for intravascular extension via the renal veins and inferior vena cava. This intravascular tumor growth is referred to as tumor thrombus or IVC thrombus, and this complication can be identified in 4–36%[80] of patients carrying a diagnosis of RCC. The disease most commonly presents with microscopic or gross

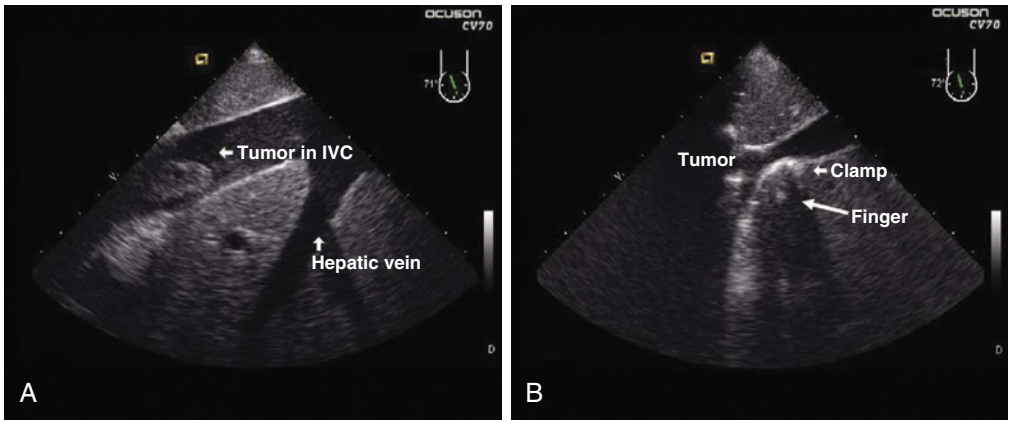


Figure 10.3 Intraoperative transesophageal echo demonstrating intrahepatic renal cell carcinoma tumor thrombus without hepatic vein compromise. The inferior vena cava can be digitally compressed and the thrombus visualized in real-time to monitor for embolic events.

hematuria (70% and 42% of cases respectively), flank pain (46%), fever (45%), anemia (23%), or incidentally (19%).[81] The imaging study of choice for diagnosis and staging remains the contrast-enhanced MRI, which offers 100% sensitivity[82] and can aid in delineating between tumor thrombus and associated bland thrombus. CT with contrast is also frequently used and offers a less expensive and time-consuming option at the expense of sensitivity (84%).[83]

Left untreated, the natural history of this disease is sobering; median disease-specific duration of survival is a mere 5 months, and only 29% of patients survive greater than 1 year. Surgical resection offers a tremendous benefit with regard to life expectancy, and patients without metastatic disease who underwent radical nephrectomy with IVC thrombectomy can expect a 5-year disease-free survival rate approaching 60%.[84] Even patients with metastatic RCC in the absence of IVC thrombus benefit greatly from surgical intervention; this was conclusively demonstrated by two pivotal randomized controlled trials, the Southwest oncology (SWOG) 8949 trial by Flanigan et al.[85] and the European Organization for Research and Treatment of Cancer (EORTC) 30947 trial by Mickisch et al.[86] Both trials compared interferon treatment to radical nephrectomy plus interferon, and both trials conclusively demonstrated survival benefit to the surgical arm. This finding appears to apply to those patients with IVC thrombus as well. Our group has recently published a case series of 76 patients with metastatic RCC with level II–IV IVC thrombus who underwent cytoreductive nephrectomy with IVC thrombectomy and demonstrated increased life expectancy to a median of 14 months.[87] Despite these promising results, it must be acknowledged that an operation of this magnitude is associated with an elevated rate of morbidity and mortality. A study by Abel et al. showed a 10% perioperative mortality rate and 34% major complication rate for advanced stage (level III–IV) IVC thrombus. Multivariate analysis highlighted poor performance status and low serum albumin as two independent risk factors associated with poor outcomes.[88] Taken together, these data suggest that surgical management of RCC with IVC thrombus remains a primary therapeutic option for both localized and metastatic renal cell carcinoma in patients with good performance and nutrition status and minimal comorbidities.

Surgical planning for radical nephrectomy and IVC thrombectomy is critically important to achieving the best outcomes, and the surgical approach and intraoperative management is predominately influenced by the level of IVC extension. The extent of IVC thrombus can be described using a number of classification schemes, but the majority of providers now use the Mayo classification scheme first described by Neves and Zincke.[89] Briefly, this scheme describes the severity of the thrombus by the extent of migration from the kidney; this ranges from level I thrombus (confined to or within 2 cm from the renal vein confluence) to level IV thrombus (above the diaphragm or into the atrium). Interestingly, recent data from our group and others suggest that the level of thrombus appears to have minimal bearing on outcomes.[87,90] Regardless of stage, in our practice the abdominal incision is almost exclusively a transverse or chevron incision. We almost always employ intraoperative transesophageal echo (TEE) to visually identify the extent of the IVC thrombus in real time for clamp placement and to monitor for embolic events (Fig. 10.3). Beyond this, however, the surgical approach varies widely depending on the stage of thrombus being excised.

Tumors with level I thrombus can be approached in a manner similar to a standard open radical nephrectomy. We typically focus on early arterial ligation to minimize renal inflow and subsequent blood loss. Depending on the specific subtype of disease, significant venous collateralization can be present, and these small thin-walled vessels bleed profusely if the artery is left intact. Once the artery has been ligated, we mobilize the entire kidney and then carefully obtain circumferential control of the renal vein. If the tumor thrombus is isolated to the renal vein and the IVC confluence, then it is possible to simultaneously gently palpate and retract the thrombus toward the kidney while applying a partially occlusive caval clamp to preserve the majority of venous return. We then resect the renal vein and a cuff of vena cava and then perform our cavorrhaphy with 4-0 sutures placed in the apex and run continuously to the center of the defect and tied together. If following this maneuver it becomes clear that the thrombus excision remains incomplete and the thrombus remains, then the clamp is left in place and circumferential control of the IVC and left renal vein is obtained.

Tumors with level II thrombus require more extensive IVC dissection and mobilization. It is critical in these lesions to identify and secure the contralateral renal vein, lumbar veins, adrenal veins, and any other small tributaries that may be present. In our experience, it is rare to identify suprarenal IVC lumbar veins, and the only posterior branch that is reliably encountered is the right adrenal vein. The caudate lobe of the liver can then be gently retracted as needed for clamp placement. If short hepatic veins are encountered while performing this maneuver, they can be ligated and divided. Once these have been identified and controlled, the IVC is controlled by first occluding the contralateral renal vein with a bulldog clamp, followed by the infrarenal IVC, and finally the suprarenal IVC. At this point the IVC is carefully palpated for the extent of thrombus. If the IVC remains distended, the surgeon should consider the possibility of inflow from an uncontrolled source. Once the IVC is decompressed, the cavotomy can be performed on the anterolateral aspect of the cava and extended as needed to facilitate thrombus extraction. Following this, the lumen should be carefully inspected, and any portions of the wall with adherent disease should be fully excised and reconstructed using primary closure or patch repair as previously described (Fig. 10.4). Once the repair is complete, we leave the final suture untied and flash the suprarenal clamps to fill the cava and vent any remaining air. We then remove clamps in the following sequence: suprarenal IVC, contralateral vein, and infrarenal IVC.

Level III lesions require extensive liver mobilization and further vascular control. This involves first dividing the falciform ligament and left triangular ligament to expose the suprahepatic IVC. The right lobe is then mobilized from the kidney in a very gentle fashion, as excessive traction can cause liver laceration and bleeding. Next, the right triangular ligament is divided using traction applied from the left side of the patient. Care must be taken to isolate and control the short hepatic veins that directly drain from the liver into the IVC. These vessels are often short and fragile, and doubly ligating them can occasionally prove to be challenging. Alternatively, the veins may be doubly clamped, divided first, and then oversewn with permanent suture. Control of these veins can be difficult and is occasionally complicated by the fact that failure to control the hepatic side can result in vein retraction into the parenchyma. If this occurs, hemostasis can be obtained by suture ligature with incorporation of the surrounding hepatic parenchyma. Once the liver is sufficiently mobilized, the surgeon should assess via both palpation and intraoperative TEE the extent of the IVC thrombus just inferior to the hepatic veins. If the thrombus can be retracted sufficiently to allow for clamp placement just below the hepatic veins, then control of hepatic outflow (and thus inflow) does not need to be compromised and IVC control proceeds in a similar fashion to level II thrombi. If, however, the thrombus remains at or above the hepatic veins, then the porta hepatis (portal vein and hepatic artery) must be controlled. This can be accomplished via the Pringle maneuver, which involves placement of an atraumatic vascular clamp to the porta hepatis. First, however, the contralateral renal vein is excluded, followed by the proximal IVC (including the second lumbar vein). At this stage the Pringle maneuver is performed, and finally the suprahepatic IVC is clamped. If the tumor originates from the left kidney and extends through the left renal vein, we almost always occlude the right renal artery and vein so that the right kidney does not become distended due to only venous outflow obstruction. Working quickly to minimize liver ischemia, an anterolateral cavotomy, which includes the affected renal vein, is then performed and the thrombus removed. Once complete, the IVC is controlled below the hepatic venous outflow and the suprahepatic and Pringle clamps removed. The repair then proceeds as before and the nephrectomy is completed.

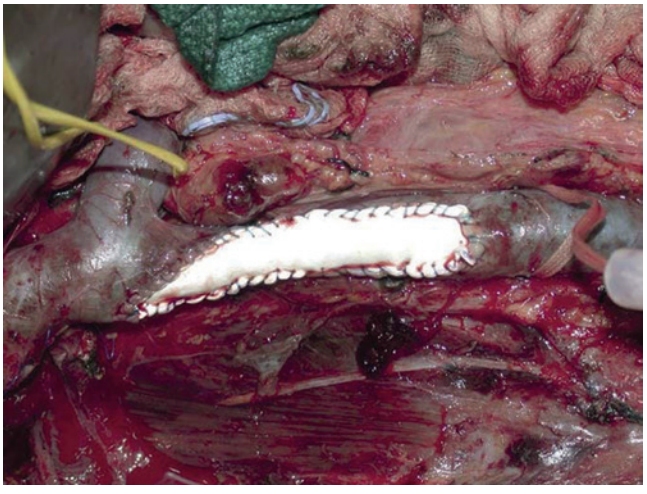


Figure 10.4 Inferior vena cava (IVC) reconstruction using bovine pericardial patch following right-sided radical nephrectomy and IVC thrombectomy with partial IVC resection.

In contrast to the lesions described above, level IV (supradiaphragmatic) lesions require collaboration with cardiac surgery and intrapericardial control via median sternotomy. This can be accomplished using deep hypothermic circulatory arrest (DHCA), veno–veno bypass, or, more commonly, cardiopulmonary bypass (CPB), with or without concomitant DHCA. Historically we used DHCA alone but found the complication rate to be unacceptably high. More recently we now favor the use of CPB. Interestingly the use of DHCA in conjunction with CPB has been shown in a relatively small series to be associated with significantly decreased perioperative mortality.[91] While promising, these results warrant further investigation and validation. Of note, the use of bypass also necessitates maximal anticoagulation, and meticulous hemostasis in the abdomen is critical to prevent excessive blood loss.

Historically many centers have combined the above surgical techniques with preoperative renal artery embolization, under the hypothesis that decreased or absent arterial inflow may confer diminished blood loss, increased edema and clearer resection planes, and/or early ligation of the renal vein. Data from our institution, however, does not support these hypotheses and instead surprisingly suggested that preoperative embolization conferred a fivefold higher risk of perioperative death and increased transfusion and intensive care requirements when compared to surgery alone.[92] We now no longer embolize these masses prior to surgery except in extenuating circumstances, such as Budd–Chiari syndrome from IVC thrombus obstructing hepatic outflow. These patients are extremely poor operative

candidates and have a significantly elevated rate of perioperative mortality and likely benefit from renal artery embolization and subsequent surgery if hepatic outflow can be restored and the sequelae from it reversed.

Finally, recent reports from several groups have described the application of robotic techniques to IVC thrombus.[93–98] These reports describe successful robotic radical nephrectomy and IVC thrombectomy for level I–III disease. The theoretical benefits of such a procedure include decreased morbidity and postoperative pain. From a practical standpoint, much of the operation is conducted in a similar stepwise fashion as described for open procedures. After initial exposure and dissection, the renal artery is controlled using Hem-o-lok clips. Minimally invasive control of the vessels is accomplished using Rummel tourniquets, and the renal vein is transected using an Endo GIA stapler (or alternatively the tumor and IVC thrombus can be removed en bloc).[98] Outcomes to date using this approach appear promising, with a short length of stay (3–5 days) and minimal blood loss (150–375 mL), but further work is necessary to refine these techniques before this approach can be widely adopted.

References

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Chapter 10 Questions

1. Which of the following renal artery control strategies is contraindicated?
   a. Endo GIA stapler with vascular load in a living donor nephrectomy
   b. Endo TA stapler in in radical nephrectomy
   c. Placement of two Hem-o-lock clips in laparoscopic living donor nephrectomy
   d. Suture ligation in a radical nephrectomy
   e. Statinsky clamp across hilum during profuse bleeding

2. Which of the following hemostatic agents must be used with caution in diabetic patients?
   a. Gelfoam
   b. Tisseel
   c. HemCon
   d. Arista
   e. Extrinsic pressure

3. Why should protamine be given as a test dose prior to full heparin reversal?
   a. Paradoxical reaction causing hemorrhage
   b. Hypotension
   c. Hypertension
   d. Arrhythmias
   e. Hypoxia

4. Which of the following is the most devastating consequence that can occur during left radical nephrectomy?
   a. Lumbar artery injury
   b. Ligation of the superior mesenteric artery
   c. Splenic artery laceration
   d. Pseudoaneurysm formation
   e. Acute kidney injury

5. What is the median disease-specific survival for untreated renal cell carcinoma with inferior vena cava thrombus?
   a. 3 months
   b. 5 months
   c. 10 months
   d. 3 years
   e. 6 years

6. According to the Neves classification, a patient with renal cell carcinoma with tumor thrombus extending into the infrahepatic inferior vena cava (IVC) is classified as level:
   a. I
   b. II
   c. III
   d. IV
   e. Depends on the laterality of the primary lesion

7. A patient undergoes vascular repair following iliac artery injury, and the repair subsequently becomes stenotic to 50% of its initial diameter. According to the law of Pouiselle, the flow through this stenotic vessel is changed to:
   a. $\frac{1}{2}$ of initial flow rate
   b. $\frac{1}{4}$ of initial flow rate
   c. $\frac{1}{8}$ of initial flow rate
   d. $\frac{1}{16}$ of initial flow rate
   e. Twice the initial flow rate

8. Upon injury to a major vascular structure, which of the following initial maneuvers can minimize blood loss prior to undergoing definitive repair?
   a. Massive transfusion
   b. Digital pressure
   c. Bovie electrocautery
   d. Intraoperative vascular surgery consult
   e. Application of Gelfoam

9. A 23-month-old male is diagnosed with Wilms' tumor and undergoes surgical resection. Intraoperatively the superior mesenteric artery is transected. Which of the following suture materials is most appropriate for repair?
   a. Polypropylene
   b. Polydioxanone
   c. Polyglactin
   d. Polytetrafluoroethylene
   e. Silk

10. What are the three components of Virchow's Triad?
    a. Hemostasis, thrombolysis, coagulation
    b. Hypocoagulability, thrombocytopenia, anemia
    c. Hypercoagulability, endothelial damage, stasis
    d. Hemorrhage, hypotension, tachycardia
    e. Hypercoagulability, hypocoagulability, shock

Answers

1. **c.** Hem-o-lock clips are contraindicated in living donor nephrectomy per FDA regulations.
2. **d.** Arista is a polysaccharide that can increase blood glucose levels. Caution is recommended when using >50 g in diabetic patients.
3. **b.** Protamine can cause anaphylactoid reaction, particularly in diabetic patients on neutral protamine Hagedorn (NPH) insulin.
4. **b.** Superior mesenteric artery ligation, while rare, will – if unidentified – rapidly cause bowel ischemia, clinical deterioration, and death.
5. **b.** Without surgical intervention, the median life expectancy is a mere 5 months.
6. **b.** A level II thrombus extends into the IVC but remains infrahepatic in location.
7. **d.** Pouiselle flow dictates that flow is inversely proportional to the fourth power of the radius.
8. **b.** While the other interventions may be indicated in some cases, digital pressure is the only intervention listed that will minimize intraoperative blood loss.
9. **b.** Typically vascular anastomoses are performed with permanent suture, but in this pediatric setting, repair using a slowly resorbing suture material such as polydioxanone (PDS) is indicated.
10. **c.** Virchow's triad (hypercoagulability, endothelial damage, and stasis) describes the three fundamental principles that contribute to thrombosis.

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11 Management of Bowel Complications

BROCK O'NEIL and SAM S. CHANG

CHAPTER OUTLINE

Ileus
Bowel Preparation
Bowel Injury
Bowel Leak, Abscess, and Fistula
Bowel Obstruction
Ogilvie's Syndrome
Chapter 11 Questions and Answers

KEY POINTS

1. Prolonged ileus lengthens the patient's discomfort, increases the need for parenteral nutritional support, and constitutes the most common reason for delayed discharge after abdominal surgery.
2. Following surgical procedures, the small intestine first regains function within 24 hours, the stomach in 24 to 48 hours, and the colon in 3 to 5 days.
3. Enhanced recovery after surgery protocols (standardized care pathways) that comprehensively incorporate strategies to prevent ileus, including elimination of routine use of perioperative bowel preparation and nasogastric decompression, minimization of narcotic pain medication, and utilization of μ-receptor antagonists improve time to return of bowel function.
4. Once an intraabdominal abscess has been identified, antibiotic treatment is not adequate; the abscess must be drained.
5. The most important initial step in treating a patient with bowel obstruction is to replace intravascular volume. Surgical intervention should occur early in patients with complete bowel obstruction. In approximately 80% of patients, a partial bowel obstruction will resolve on its own.
6. Bowel injury, including rectal injury, recognized intraoperatively can usually be primarily repaired with consideration for proximal bowel diversion in certain circumstances. Delayed recognition of bowel injury can lead to profound illness and requires reoperation.
7. Fistula after urinary diversion is uncommon, and initial management focuses on diversion of urine away from the fistula and delayed repair when these measures do not result in resolution.
8. When conservative and pharmacologic management of Ogilvie's syndrome has failed, colonic diameter measures >12 cm, colon size is increasing rapidly, or the duration is >3 days, the colon should be decompressed.

Urologists are often faced with clinical and operative decisions that involve the bowel. The bowel can be invaded by urologic tumors, may be used as a urinary conduit, and simply may be in the way of complex urologic procedures. The approach to some common problems associated with operating in the abdominal cavity and the management of potential complications associated with the gastrointestinal tract (GI) are outlined in this chapter (Table 11.1).

Ileus

Ileus, or intestinal paralysis, represents delay in coordinated bowel activity and is experienced by most patients following an intraperitoneal procedure but can also be exhibited following extraperitoneal procedures. This condition falls on a continuum from a normal physiologic process of recovery to a prolonged delay in bowel motility and function and is characterized by abdominal distention, decrease in bowel sounds, delayed passage of flatus and defecation, and accumulation of gas and fluids in the bowel that may result in nausea and vomiting. Prolonged ileus lengthens the patient's discomfort, increases the need for parenteral nutritional support, and constitutes the most common reason for the delayed discharge after abdominal surgery occurring in 10–22% of patients undergoing major abdominal surgery.[1–3] The economic impact of ileus in the United States is estimated to be $750 million to $1 billion annually.

Following abdominal surgical procedures, each section of the GI tract recovers at a different rate. The small

Table 11.1 Summary of Bowel Complications and Management Principles

Complication	Incidence	Management Principles
Abscess	1.1–3.6%	Percutaneous drainage, washout in specific cases
Bowel leak	<1%	Early: reoperation and repair; late: control leak, delayed repair with possible bowel diversion
Bowel obstruction	1.6–16%	Fluid resuscitation, reoperation
Ileus	10–22%	Nasogastric decompression, nonoperative support (e.g., enteral nutrition)
Rectal injury	<1%	Intraoperative recognition: primary repair with consideration for proximal bowel diversion in certain cases Delayed recognition: washout and proximal bowel diversion
Urinary fistula	3–4%	Diversion of urine, delayed surgical repair if doesn't resolve

intestine first regains function within 24 hours, the stomach in 24 to 48 hours, and the colon in 3 to 5 days. Therefore once the patient has experienced flatus following an operation, it is likely that the colon and the remaining GI tract have recovered.

The pathophysiologic mechanism of ileus is incompletely understood but appears multifactorial, involving neurogenic, inflammatory, and pharmacologic mechanisms.[4] Neurogenic hypotheses suggest ileus may be a result of activation of a spinal reflex that inhibits GI motility, which is further reinforced through sympathetic hyperactivity induced by the stress of surgical trauma.[5,6] For this reason, epidural/spinal anesthesia has been suggested to prevent prolonged ileus but must be adequately proximal to block the sympathetic chain and should utilize local anesthetics rather than narcotic agents to maximize effectiveness.[7,8] Narcotic medication, frequently used in the perioperative setting, contributes to prolonged ileus through activation of μ-opioid receptors in the GI tract.[9]

Electrolyte disturbances including hypomagnesemia, hyponatremia, and hypokalemia have all been cited as contributing to prolonged ileus.[4] Additional contributors include prolonged operative time, significant manipulation of the bowel, increased blood loss, and body mass index.[2,10] Inflammation is thought to contribute to postoperative ileus as a systemic response to surgery as well as due to direct manipulation of the bowel through both the innate and adaptive immune system and is the subject of research to identify pharmacologic interventions that may reduce its duration.[11] It may be that the benefit in terms of shorter duration of ileus with laparoscopy compared to open surgery despite average longer operating times is due to the induction of less inflammation through a smaller degree of manipulation and/or improved temperature and humidity control of the bowel.[12]

Several abnormalities common in urologic procedures can initiate and propagate ileus. Ileus can also be a sign of a more severe condition, and urologic patients experiencing a prolonged return of bowel function should be assessed for sources of electrolyte abnormalities and infection including intraabdominal abscess, bowel leak, urinary tract infection or leak, and urinoma. If any of these conditions are identified, correction is necessary to aid in the resolution of ileus and to prevent further development of complications. Finally, the acute withdrawal or accelerated taper of steroids in the postoperative period has been shown to prolong or even precipitate ileus and is corrected with bolus steroid administration.[13]

In some patients, ileus may continue despite best efforts at prevention and treatment, and the mainstay of treatment remains nasogastric decompression. It is not our routine practice to surgically intervene in the setting of prolonged ileus when bowel obstruction and other inciting conditions have been ruled out or otherwise addressed. While the use of routine nasogastric decompression for abdominal procedures has fallen out of favor due to increased rates of pulmonary complications such as fever, atelectasis, and pneumonia as well as higher rates of wound complications and prolonged hospital length of stay,[14] if the patient does become distended or experiences severe nausea or vomiting, a nasogastric tube should be placed.

Parenteral nutrition should be started if it is anticipated that prolonged ileus will continue (>7–10 days). Once bowel obstruction has been ruled out and the correctable abnormalities have been addressed, a trial of prokinetic agents may be considered; although, while this route may be potentially helpful for symptomatic relief of nausea, their use has not been consistently shown to reduce time of ileus.[15]

Prevention of prolonged postoperative ileus remains a critical component of the management of the urologic patient. Minimization of narcotics with substitution/addition of nonsteroidal antiinflammatory medications (NSAIDs) or epidural, spinal, or regional (e.g., On-Q) local anesthetics has been shown to have beneficial impact on ileus.[7,8,16] Perioperative use of peripheral μ-receptor antagonists (e.g., alvimopan) also reduces the time of postoperative ileus and may represent a cost-effective strategy.[17,18] Other proven strategies include early enteral feeding,[19] chewing sugar-free gum,[20] early administration of coffee,[21] electroacupuncture,[22] and readaptation of the peritoneum after cystectomy and pelvic lymphadenectomy.[23] Early postoperative ambulation may not expedite GI tract function recovery but is encouraged for benefits in reducing thromboembolism and pulmonary complications.[24] Enhanced recovery protocols (standardized clinical pathways) that incorporate some or all of these strategies have shown significant reductions in hospital stays without increasing perioperative complications or readmissions.[25,26]

Bowel Preparation

Considerable debate continues on the value of preoperative mechanical and/or antibiotic bowel preparation for the prevention of bowel-related complications. Dogma in favor of bowel preparation has been around for over 50 years and was challenged more recently with several trials and a Cochrane review suggesting no advantage for colectomy in terms of bowel anastomosis leaks, deep abscess, or

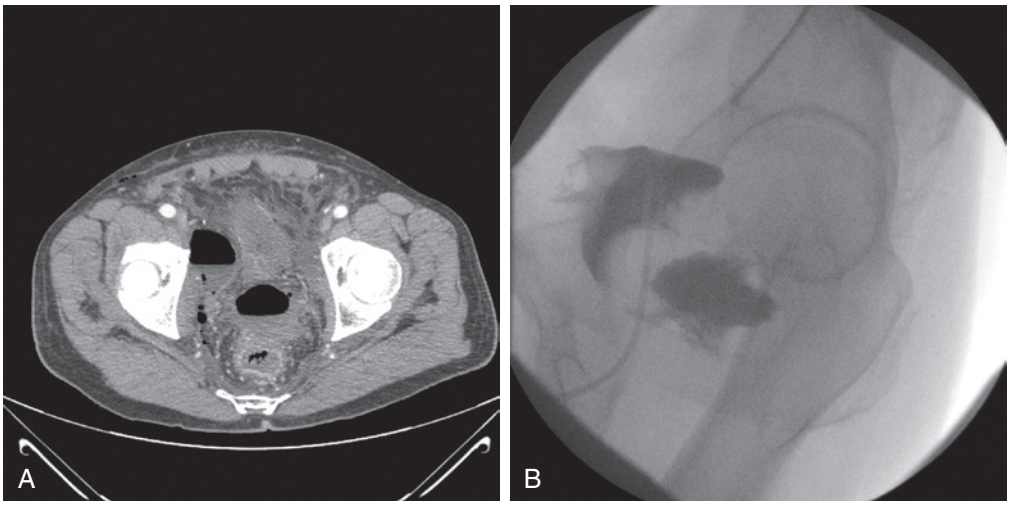


Figure 11.1 A, CT after radical prostatectomy showing large free air between bladder and rectum and lateral to the bladder in a patient with a rectal injury not recognized at the time of surgery requiring proximal diversion of bowel. B, Subsequent cystogram showing development of fistula between urethra and rectum.

superficial surgical-site infection and with possible worsening with prolonged ileus.[27,28] Largely based on these data, several enhanced recovery protocols have eliminated routine use of bowel preparation for radical cystectomy patients.[25,26,29,30] Additional data suggest it can be safely eliminated with radical prostatectomy.[31] However, recent retrospective studies now suggest mechanical preparation along with enteral antibiotic preparation reduces infectious complications, anastomotic leak, and ileus in patients undergoing colectomy.[32,33] It is unknown whether these data translate to urologic patients undergoing surgical manipulation of small bowel rather than colon.

Bowel Injury

Any procedure in or near the abdomen risks inadvertent bowel injury with reports after cystectomy,[34] laparoscopy,[35] percutaneous nephrolithotomy,[36] suprapubic tube placement,[37] and even transvaginal surgery.[38] A simple serosal injury should be oversewn with Lembert-type suture, usually 3-0 silk. If the bowel is perforated, the approach varies depending on the size and location of the injury as well as whether the injury involved electrocautery. When the majority of the circumference of the bowel is violated the segment does not appear viable, or if the injury was caused by electrocautery, segmental resection should be performed. The small bowel can usually be reconnected safely. The large bowel can also often be reconnected, as long as fecal impaction or spillage is minimal.

If the bowel is perforated but the perforation does not appear to involve a large segment or circumference, primary repair in two layers with an inner layer of 3-0 polydioxanone (PDS) and an outer layer of interrupted 3-0 silk suture can be used. Closing the injury transverse to the longitudinal axis of the bowel should be considered so that the luminal diameter is not compromised. One may consider proximal bowel diversion if the patient is immunocompromised, has poor nutritional status, has had prior radiation of the involved segment, or there is gross contamination by colonic contents.

Delayed recognition of bowel injury typically presents with prolonged ileus, abscess (contained leak), or intraperitoneal sepsis (uncontrolled leak), and these patients can be profoundly ill. Initial presentation after laparoscopy is often more subtle, and patients may simply demonstrate pain at a single trocar, abdominal distention, diarrhea, and leukopenia.[35] Surgical exploration and washout are indicated in patients with uncontrolled leak to gain source control and generally requires proximal diversion of the bowel. Consultation with general or colorectal surgery is often recommended in this setting to assist with bowel repair and diversion. Controlled leak (abscess) or retroperitoneal bowel injury in a patient who is otherwise stable may be successfully managed with percutaneous drainage.

Rectal injury represents a special case of bowel injury of specific interest to urologists. It has been reported in less than 1% of cases in modern prostatectomy series[39,40] (Fig. 11.1). Recognition of the injury is generally intraoperative with minimal spillage of rectal contents. In this case, primary closure in two or three layers with absorbable suture has been described without diverting colostomy in both open and laparoscopic/robotic series. A peritoneal or omental flap may be used to interpose between the repair and the urethra-bladder anastomosis. Fecal diversion should be more strongly considered in the setting of an immunocompromised patient or prior pelvic radiation. Recto-urethral fistula uncommonly develops after primary repair (2/16 in one series),[40] management of which is discussed elsewhere in this text. Rectal injury during cystectomy can be managed similarly. However, avoidance of urinary diversion that will place suture lines directly over rectal repair should be considered. Delayed presentation of rectal injury, thought to be caused by thermal injury, typically presents with bloody stool or pneumaturia and is initially managed by washout and fecal diversion.

Bowel Leak, Abscess, and Fistula

Procedures that require anastomosis of bowel segments, as are commonly performed in urology, risk development of bowel leakage. This can present in a variety of manners including enteric contents captured in drains, intrabdominal or pelvic abscess, or development of a fistula.

Leakage from bowel anastomosis after urologic surgery is rare.[3,41] Patients may present with eneteric contents from a surgical drain, persistent ileus, leukocytosis, or fevers. Reoperation and repair may be considered in the early postoperative period. However, presentation of anastomotic leak has been reported over 30 days postoperatively, and reoperation after 7–10 days after the initial surgery is often very difficult due to edema and adhesions and is likely to result in additional harm.[42] In this case, management focuses on control of the enteric contents through drainage and delayed surgical repair.

An intraabdominal abscess represents a walled-off infection and collection of bacteria, purulence, blood, and possibly enteric contents, urine, or foreign material. Most intraabdominal abscesses develop in the postoperative period and have been reported in 1.1% to 3.6% of patients after cystectomy with urinary diversion.[3,43] The diagnosis should be suspected in a patient who is not progressing adequately following an operation. Ileus, abdominal distention, and anorexia are common symptoms. Spiking fevers are common but may be masked in immunosuppressed patients, in elderly patients, and in patients receiving antibiotics.

Diagnosis is made by ultrasound or CT scan (Fig. 11.2). Treatment of the abscess requires drainage as antibiotics alone will not provide adequate resolution. For most intraabdominal, pelvic, and retroperitoneal abscesses, a percutaneous approach should be attempted before operative intervention.[44] In general, a pigtail catheter should be left in the abscess cavity and removed when drainage has subsided. Catheter drainage also allows for additional management decisions including assessment for ongoing urine or bowel leakage as contributing factors. The indications for open surgical drainage include inability to safely drain due to location, failure of percutaneous drainage, or presence of interloop abscesses.

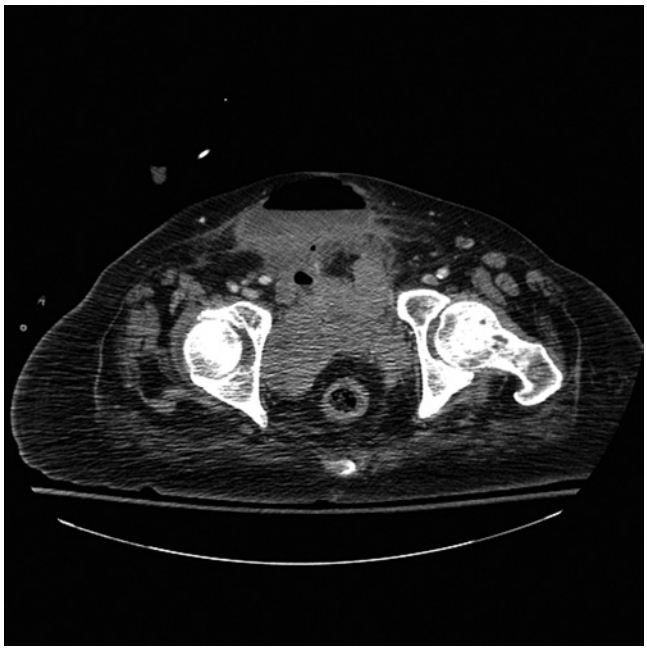


Figure 11.2 CT with IV contrast showing a subcutaneous abscess tracking from an intraabdominal location after radical cystectomy.

Antibiotic use should be directed by culture information until signs of infection have resolved. It is not necessary to continue antibiotics for long periods after adequate drainage. If the patient does not improve within 24 to 48 hours, additional imaging should be performed to ensure adequate drainage.

Fistula is defined as the abnormal communication between two structures and occurs not uncommonly in urologic surgery. Fistula to bowel used for urinary diversion occurs in up to 4% after radical cystectomy[45,46] and between neobladder and vagina in up to 3.1%.[47] Initial conservative management with maximal urinary drainage with an indwelling catheter and low residual diet may be undertaken.[48] Surgical repair should not be undertaken in the acute setting due to the high risk for failure and potential to cause further injury. Surgical management principles when conservative management is not successful include (1) locating and excising the fistula tract, (2) closure of neobladder defect in two layers, and (3) interposition of healthy tissue with an omental flap. Temporary proximal diversion of bowel can also be utilized to maximize successful repair.[45]

Vesicoenteric fistula, or the abnormal communication between bladder and bowel, is rare and most commonly occurs as a result of inflammatory and neoplastic processes of the bowel rather than as a result of urologic intervention. Management principles are similar to enterocutaneous fistula and include diversion of fluid crossing the fistula such as urine in a fistula to an ileal conduit. Patients often present with infection and may have undrained fluid collections leading to intraabdominal abscess that both require treatment.

Bowel Obstruction

Intraabdominal adhesions are the most common cause of bowel obstruction in the United States. The incidence of postoperative obstruction varies with the approach and procedure performed but is much less common. The short- and long-term risk of obstruction ranges from 1.6% to 16.0% after cystectomy[41,43,49,50] and 5% for retroperitoneal lymph node dissection.[51] Cases have been reported involving less invasive procedures including laparoscopy[50,52] and even penile prosthesis placement.[53]

Intestinal obstruction in the early postoperative period must be distinguished from ileus. Ileus is associated with many intraabdominal and extraabdominal processes that interfere with normal bowel motility and resolves spontaneously once the provoking source has been addressed.

Most patients with bowel obstruction exhibit abdominal pain, nausea, vomiting, obstipation, and abdominal distention. Delayed return of bowel function may also represent

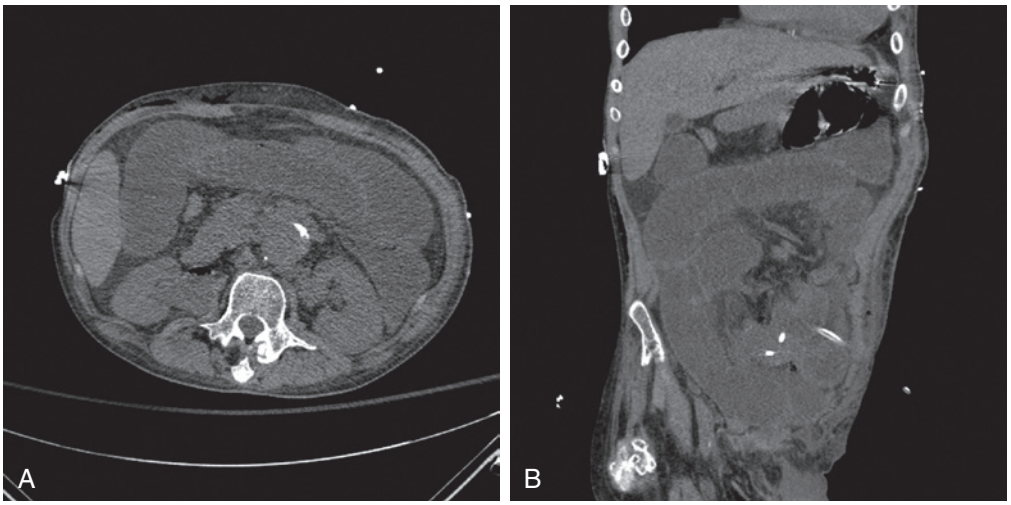


Figure 11.3 CT showing bowel obstruction after radical cystectomy with ileal conduit and bilateral ureteral stent placement. A, Axial. B, Coronal.

bowel obstruction. Pain is usually intermittent and may become constant if the bowel becomes compromised. However, pain severity may decrease over time as a result of bowel fatigue and atony. Patients usually become profoundly intravascularly depleted, manifested by orthostatic hypotension, tachycardia, and low urinary output. Eventually, patients manifest hypokalemic, hypochloremic metabolic alkalosis secondary to gastric loss of hydrogen and chloride and renal compensation of potassium wasting.

In patients with suspected bowel obstruction radiologic studies are indicated. Computed tomography (CT) scanning has sensitivity and specificity of >90% for small bowel obstruction (Fig. 11.3).[54] In addition, it is capable of detecting the cause as well as the presence of closed-loop obstruction and strangulation and therefore is usually the first radiologic examination performed. In contrast to ileus, which may also produce air–fluid levels, gas is not seen through the entire GI tract, especially distal to the point of obstruction.

The most important initial step in treating a patient with bowel obstruction is to replace intravascular volume. The patient may require several liters of fluid before rehydration is complete. Serum electrolytes should be monitored and adjusted as indicated. Antibiotics should not be used unless the patient is to go to the operating room or ischemic bowel is considered. Finally, a nasogastric tube should be placed to decompress the GI tract proximal to the obstruction, and oral intake should be strictly limited.

Strangulation of the bowel is a potential complication of obstruction and must be quickly corrected to avoid a poor outcome as it carries a much higher mortality rate than simple obstruction. The diagnosis of bowel strangulation is made by a combination of signs and laboratory findings including fever, tachycardia, nausea, and vomiting. Physical examination reveals localized tenderness. Laboratory findings include leukocytosis and elevated serum lactic acid or amylase levels.[55] When a strangulated bowel is suspected, operative exploration is mandatory following adequate resuscitation.

Internal hernia through the bowel mesentery is a special type of bowel strangulation that can occur after urologic surgery and often results in catastrophic outcomes.[56] Closure of any mesenteric defect during the procedure, especially with diversion of bowel as with urinary diversion, is commonly done to reduce this risk, and evidence from bariatric surgery supports this practice.[57]

Partial bowel obstruction in the immediate postoperative period almost always resolves with conservative treatment. The initially aggressive nature of adhesions usually improves and leads to resolution of symptoms. In nearly 90% of these patients, the condition resolves with nasogastric decompression. Two-thirds of these bowel obstructions resolve within 7 days and the remainder resolve within 14 days.[58] During this period, parenteral nutrition should be considered. If the condition has not resolved after 2 weeks of conservative measures, reoperation may be considered.

Once a determination has been made that reoperation is necessary to relieve obstruction, the patient should be prepared with perioperative antibiotics and careful induction of general anesthesia to avoid aspiration. Special care should be taken while entering the abdomen to avoid injury to the intestine.

On entering the abdomen, the surgeon should note the character of the peritoneal fluid. Turbid or dark fluid is an indication of ischemic bowel. The entire intestine should be freed of adhesions using sharp dissection from the ligament of Treitz to the sigmoid colon. Blunt dissection tends to injure the bowel serosa. The bowel should be repaired if the mucosa is visible. A point of transition between proximal dilated and distal decompressed bowel should be identified and the inciting cause corrected. If one determines that completely dissecting the bowel free of adhesions is dangerous, a bypass of the segment should be considered. The intestine should be examined for coloration, presence of motility, and arterial pulsations or Doppler signals. If dead bowel is identified, a segmental resection with primary anastomosis should be performed.

Laparoscopy offers the potential for a minimally invasive approach for diagnostic as well as therapeutic intervention. Several clinical studies have demonstrated that patients with bowel obstruction who underwent laparoscopic management of bowel obstruction had fewer postoperative

complications, quicker recovery of bowel movements, and a shorter hospital stay than those who underwent conventional laparotomy.[59,60] However, complications such as perforations may be more common overall in the laparoscopic group, and patients with two or more previous laparotomies have demonstrated higher rates of these complications. Therefore proper patient selection is critical to maximizing outcomes.[61]

Ogilvie's Syndrome

Ogilvie's syndrome, or colonic pseudo-obstruction, was first described by Sir William Ogilvie in the *British Medical Journal* in 1948. This condition manifests by colonic distention that appears mechanical but is actually functional. It is thought that this condition results from an autonomic imbalance leading to increased sympathetic tone or excessive parasympathetic suppression. The precise physiologic mechanism, however, is still poorly understood.

Ogilvie's syndrome occurs most commonly in patients who are long-term residents of a nursing home or psychiatric ward with conditions such as stroke, dementia, orthopedic procedures, sepsis, neuroleptic use, narcotic use, or electrolyte abnormalities but can also present after gynecologic and urologic surgeries. Most patients present with massive abdominal distention and few other complaints. Patients rarely complain of much pain. Physical examination reveals a distended and tympanic abdomen with diminished bowel sounds. Fever and leukocytosis are rare. The presence of marked abdominal pain, fever, and leukocytosis should alert the physician to ischemia or perforation. When ischemia or perforation is present, the mortality rate is ≤40% compared with 15% in patients with viable bowel.[62]

The diagnostic process begins with flat and upright abdominal radiographs, which demonstrate a massively dilated colon beginning in the cecum and extending no farther than the splenic flexure. One must be sure that volvulus or bowel obstruction is not the cause of the colonic distention. A gentle enema contrast study can be ordered to rule out these causes and confirm the diagnosis.

For most patients, treatment is conservative. Electrolyte abnormalities should be corrected and the medication list reviewed. Patients with a cecum measuring <12 cm should receive nothing by mouth, and a nasogastric tube should be placed. These patients should be monitored with serial examinations and abdominal films.

Patients who do not show improvement with conservative management may respond to neostigmine, a reversible acetylcholinesterase inhibitor. Neostigmine, administered intravenously, results in stimulation of muscarinic parasympathetic receptors and contraction of the affected colon. A randomized, double-blind, placebo-controlled trial found that 10 of 11 patients who received neostigmine had colonic decompression but none in the placebo group did.[63] Because neostigmine can cause bradycardia, bronchoconstriction, and tremors, close monitoring of cardiorespiratory status is required, and any toxicity should be treated with atropine.

When conservative and pharmacologic management fails, colonic diameter measures >12 cm, colon size is increasing rapidly, or the duration is >3 days, the colon should be decompressed colonoscopically with placement of a long rectal compression tube.[64,65] Surgical management is indicated in patients with ischemia or perforation or when pharmacologic methods and decompression have failed.

References

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Chapter 11 Questions

1. Postoperative day 4 after radical cystectomy with neobladder, a 72-year-old male develops severe nausea and emesis. He is otherwise stable without fever or leukocytosis but does have a distended abdomen. A nasogastric tube is placed with return 750 mL of bilious material. Which of the following has been implicated in the development of the most likely cause of his condition?
   a. Decreased sympathetic outflow
   b. Use of NSAIDs
   c. μ-receptor activation
   d. All of the above
   e. None of the above

2. A patient who underwent a radical cystectomy with ileal conduit was discharged on postoperative day 5. Fourteen days later he presents to the emergency room with fever, distended abdomen, and leukocytosis. A CT scan is performed that shows a rim-enhancing fluid collection in the pelvis. What is the appropriate management?
   a. Percutaneous drainage
   b. Observation only
   c. Prescribe an antibiotic and observation
   d. Take the patient to the operating room for open surgical drainage
   e. Take the patient to the operating room for repair of ureteral anastomosis

3. After dividing the bowel to obtain a segment and reanastomosing the divided bowel for urinary diversion during radical cystectomy, what can be done to reduce the occurrence of an internal hernia?
   a. Close the fascia with nonabsorbable suture
   b. Close the peritoneum with mesh
   c. Avoid use of an omental flap
   d. Close the mesenteric defect
   e. Keep the patient on bowel rest for 48 hours after surgery

4. An afebrile 68-year-old female underwent cystectomy with neobladder 14 months ago. She presents to the emergency room with abdominal pain, emesis, and obstipation. A CT scan is performed. Which of the following is the most likely cause of her condition?
   a. Gastric inflammation
   b. Increased sympathetic outflow
   c. μ-receptor activation
   d. Intraabdominal abscess
   e. Intraabdominal adhesions

5. A 64-year-old male undergoes a robotic-assisted laparoscopic prostatectomy and presents to your office on postoperative day 3 with diarrhea, abdominal distention, and focal but severe pain at the right most lateral trocar site. Which of the following is the most likely diagnosis?
   a. Urine leak
   b. Ileus
   c. Appendicitis
   d. Injury of ascending colon
   e. Urinary tract infection

6. A 53-year-old female who previously underwent pelvic surgery and radiation for cervical cancer undergoes pelvic exenteration with ileal conduit urinary diversion for a local cancer recurrence. Her postoperative course is complicated by prolonged ileus requiring total parenteral nutrition. On postoperative day 12, she begins draining enteric contents from the upper portion of her incision. After ensuring she does not have an undrained fluid collection within the abdomen or pelvis, which of the following is the best course of action?
   a. Continue total parenteral nutrition and strict nil per os (NPO) status
   b. Emergently explore her abdomen and repair the bowel injury
   c. Begin enteral feeding
   d. Initiate broad spectrum antibiotics
   e. Cauterize the site of the draining fluid

7. An 80-year-old male undergoes a radical nephrectomy for a 13-cm renal mass. He develops postoperative nausea and ileus, and a nasogastric tube is placed. Abdominal x-rays reveal no free air but do show air throughout the small and large bowel. His large bowel is distended to greater than 12 cm. Which of the following is an appropriate next step?
   a. Discontinue the nasogastric tube (NGT) and place a gastric tube
   b. Administer neostigmine
   c. Administer alvimopan
   d. Perform esophagogastroduodenoscopy
   e. Administer atropine

8. A 46-year-old female develops a postoperative ileus after undergoing a radical nephrectomy. Impaired motility of which of the following is most likely responsible for this process?
   a. Stomach
   b. Duodenum
   c. Small bowel
   d. Large bowel
   e. Rectum

9. All of the following strategies are helpful for preventing or reducing the duration of postoperative ileus except:
   a. Nasogastric tube drainage
   b. Alvimopan
   c. Minimization of narcotic pain medication
   d. Use of epidural anesthesia
   e. Chewing sugar-free gum

10. A 62-year-old male undergoes a radical cystectomy and ileal conduit for urothelial cell carcinoma. Prior to incision, he received a dose of an IV second-generation cephalosporin. He did not undergo a preoperative mechanical or antibiotic bowel preparation, which places him at an increased risk for which of the following?
    a. Pelvic abscess
    b. Entero-enteric anastomosis leak
    c. Entero-ureteral anastomosis leak
    d. Superficial surgical site infection
    e. None of the above

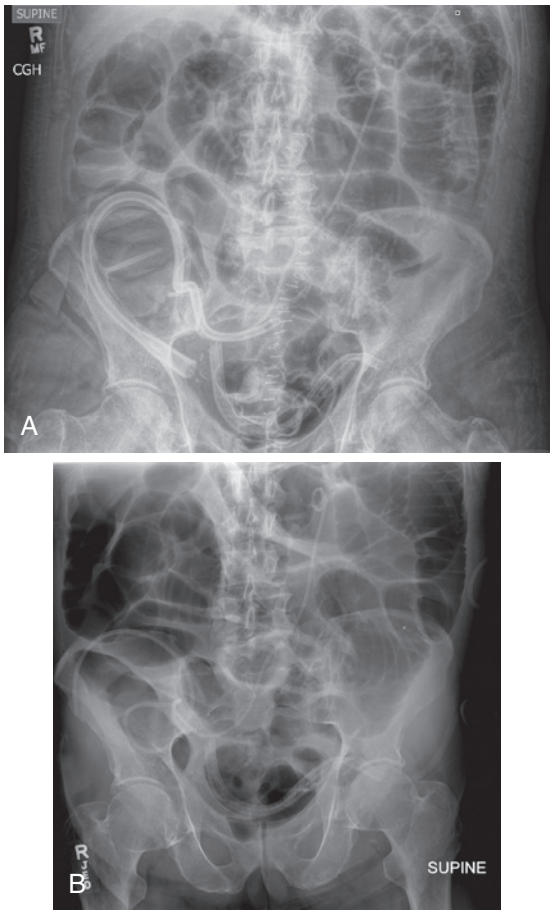
Case Studies

CASE 1

A 62-year-old male undergoes revision of a left ureteroenteric stricture due to a stricture that developed after radical cystectomy with ileal conduit urinary diversion. His postoperative course is uneventful until day 4 when he develops large volume emesis. He is afebrile, without leukocytosis, and his exam reveals a minimally tender abdomen that is distended and tympanitic. An abdominal series is obtained, and representative images (Case Fig. 11.1) are shown.

1. Which of the following is the most likely diagnosis?
   a. Bowel injury
   b. Bowel obstruction
   c. Retained foreign body
   d. Ureteroenteric leak
   e. Ileus

2. The patient continues with moderate nasogastric tube output despite occasionally passing flatus and stool. He is unable to tolerate clamping of the nasogastric tube. On postoperative day 8, which of the following is an important step in his management?
   a. Initiate total parenteral nutrition
   b. Explore abdomen to lyse adhesions



Case Figure 11.1

   c. Begin broad spectrum antibiotics
   d. Begin enteral feeding
   e. Continue current care without changes

3. He remains hospitalized for 2 weeks with persistent nausea. He is able to have the nasogastric tube removed but is unable to take any solid food and can only tolerate a few hundred milliliters of fluid per day. He remains without concerning vital signs or laboratory or imaging studies. His abdominal exam remains moderately distended and tympanitic, and a CT scan confirms no evidence of bowel obstruction. Which of the following is the next step in management?
   a. Place a gastric tube for enteral feeding directly into the stomach
   b. Make arrangements for outpatient total parenteral nutrition
   c. Place a pelvic drain
   d. Initiate alvimopan therapy
   e. Make arrangements for outpatient fluids together with oral nutrition supplements

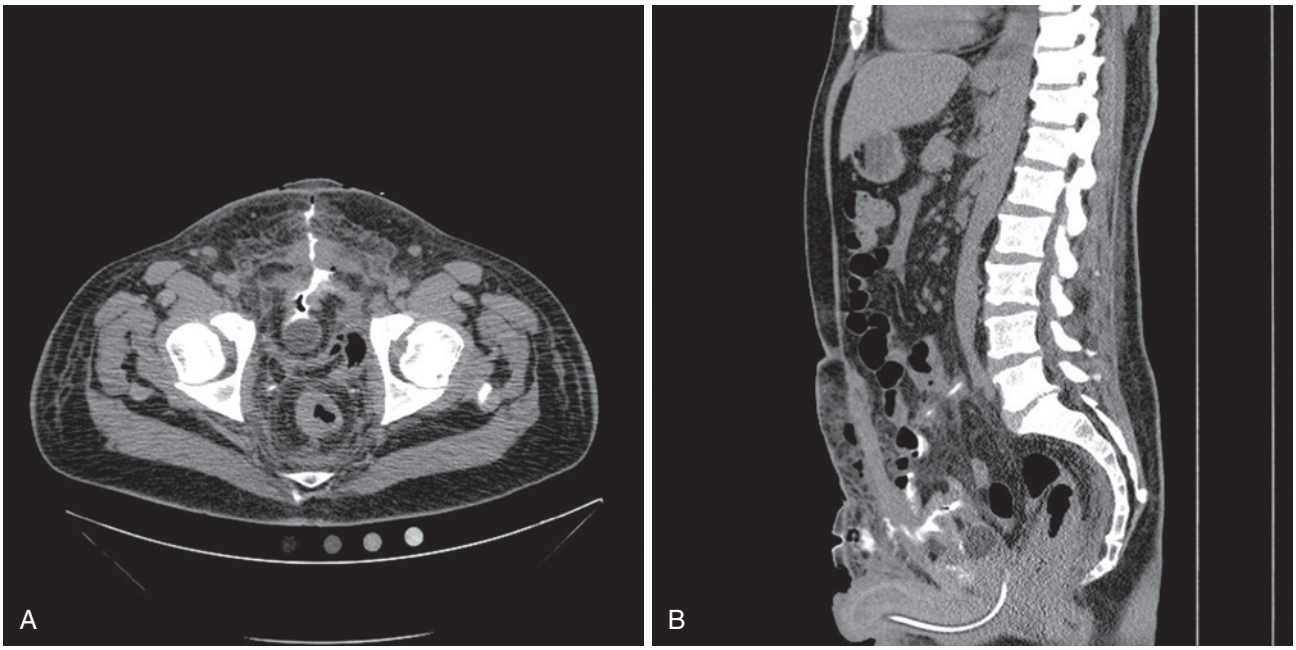
CASE 2

A 59-year-old male undergoes a radical cystoprostatectomy with ileal neobladder urinary diversion for muscle invasive bladder cancer. His initial postoperative course is uneventful, but he then presents to clinic postoperative day 12 hemodynamically stable but with fluid draining from the midline abdominal incision. A CT scan is obtained, and representative images (Case Fig. 11.2) are shown. Fluid is collected from the midline incision and found to have an elevated creatinine level.

1. What is the most likely cause for the fluid draining from the patient's incision?
   a. Bowel injury
   b. Superficial surgical site infection
   c. Urine leak from neobladder
   d. Chylous ascites
   e. Seroma

2. What is the initial management for this patient?
   a. Cauterize the fistula tract
   b. Abdominal exploration and closure
   c. Bowel rest with total parenteral nutrition
   d. Treatment of urinary tract infection
   e. Place bilateral percutaneous nephrostomy tubes

3. Despite maximal drainage of the neobladder, the drainage from the midline does not stop. After 4 months, he presents for definitive repair. Which of the following is an important principle to maximize the success of the procedure?
   a. Administration of antibiotics for 48 hours after surgery
   b. Mechanical bowel preparation
   c. Placement of ureteral stents
   d. Coverage of the repair with a tissue flap
   e. Use of mesh for closure



Case Figure 11.2

Answers

1. **c.** This patient has likely developed postoperative ileus. Increased sympathetic outflow and opioid use leading to activation of μ-receptors contribute to this process. NSAIDs may be helpful in reducing postoperative ileus by minimizing need for narcotics and reducing inflammation.
2. **a.** Intraabdominal abscesses can be identified by ultrasound or CT. Percutaneous drainage is necessary after an intraabdominal abscess has been identified. In 80–90% of cases, the abscess can be successfully drained using this approach. An antibiotic alone is not adequate. The patient should be started on an antibiotic based on the culture information. Indications for open surgical drainage include failure of percutaneous drainage, inability to percutaneously drain, or interloop abscesses. While a urine leak may be the underlying cause of an abscess, percutaneous drainage is the first step in management.
3. **d.** Internal hernias occur as a result of the protrusion of bowel through peritoneal or mesenteric defects. Closure of these defects during an operation eliminates potential defects. Fascial closure method, use of mesh, omental flap, and bowel rest do not prevent internal hernias.
4. **e.** The patient most likely has a bowel obstruction, which can be caused by adhesions after intraabdominal procedures. a–c are causes of ileus and an intraabdominal abscess is a less likely diagnosis.
5. **d.** Severe trocar site pain, diarrhea, abdominal distention, and leukopenia are consistent with an unrecognized bowel injury.
6. **a.** This patient has developed an entero-cutaneous fistula. Reoperation at this point after surgery is likely to result in more harm than benefit. Many well-drained fistulas will spontaneously close with bowel rest and total parenteral nutrition without need for surgical intervention or antibiotics.
7. **b.** This patient has developed Ogilvie's syndrome, or colonic pseudo-obstruction. When the diameter measures greater than 12 cm, the risk of perforation is substantial and warrants urgent intervention. Neostigmine, colonoscopic decompression, or placement of a cecostomy tube are all appropriate options.
8. **c.** Normal return of bowel function follows a predictable pattern of small intestine, stomach, and colon. However, impaired small bowel motility is the most likely cause of postoperative ileus.
9. **a.** While important for intraoperative management, routine use of nasogastric drainage in the postoperative period does not reduce prolonged ileus and may lead to other complications while all of the other strategies have some level of evidence to suggest benefit in reducing or preventing ileus.
10. **e.** While the quality of the evidence is not very high for urologic surgery, data from the colorectal literature suggest no increased risk for developing any of the listed complications in the setting of forgoing mechanical or antibiotic bowel preparation. In the setting of colon or rectal surgery, there does appear to be a benefit for bowel preparation. Early recovery protocols in urologic surgery that do not routinely use bowel preparation have also not demonstrated an increased risk for perioperative complications.

CASE 1

1. **e.** The abdominal x-ray shows distended loops of both large and small bowel with air in the rectum consistent with ileus. His laboratory and exam findings are also consistent with ileus.

2. **a.** The patient continues with postoperative ileus and is not able to tolerate enteral nutrition. To minimize risk from malnutrition, total parenteral nutrition should be instituted. There is no indication that he has now developed a bowel obstruction and antibiotics are not indicated.
3. **b.** Occasionally, postoperative ileus will persist for weeks after abdominal surgery and continued parenteral nutrition is needed to minimize the risk of malnutrition. Eventually the ileus will resolve, but recovery of normal gastrointestinal motility can be slow. While infection can contribute to the development of ileus, no evidence suggests he has a pelvic abscess. Enteral feeding, even if bypassing the oral route, will not be successful as the problem remains distal to the stomach. While alvimopan has been shown to decrease the time to return of bowel function, it is properly administered prior to and continued after surgery. There is no evidence that initiating therapy after 2 weeks would provide benefit. In addition, it is contraindicated in patients taking narcotics prior to initiation of therapy, which this patient was certainly taking. Finally, while it would be preferable to have the patient obtain nutrition through an oral route, he cannot take in adequate volume to obviate the need for total parenteral nutrition.

CASE 2

1. **c.** The CT scan shows inflammation and air tracking from the neobladder to the anterior wall and the elevated creatinine level on the collected fluid as consistent with a cutaneous-neobladder fistula.
2. **d.** A cutaneous fistula after urinary drainage uncommonly occurs in the postoperative setting. Treatment of infection of the urinary tract and maximizing drainage of the urine is important. Foley catheter drainage will likely be adequate, and the fistula tract may close without further intervention. Urgent treatment of the fistula is likely to cause greater harm than benefit and should not be attempted in the early postoperative period. Bowel rest with total parenteral nutrition is indicated for enterocutaneous fistula, but as the segment of bowel used for the neobladder is no longer in continuity with the GI tract, this is not necessary.
3. **d.** Repair of a fistula tract that does not heal with maximization of drainage should be undertaken in a delayed fashion. Interposition of healthy tissue between the repaired neobladder and the fascia will help to ensure a recurrent fistula does not recur.

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12 Management of Urinary Fistula

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CHAPTER OUTLINE

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KEY POINTS:

1. Vesicovaginal fistulas (VVF) occur when there is an injury to the bladder creating a communicating tract with the vagina eventually leading to seepage of urine.
2. The occurrence of trauma to the lower urinary tract during surgery for benign gynecological conditions has been classically reported as high as 76% in some series; however, more recent studies have suggested this number is much lower and <1%.
3. The clinical manifestation of urogenital fistula are dependent on the size, location (i.e. proximal or distal to the continence mechanism), and structures with which the fistula connects.
4. A targeted history and physical examination including a thorough pelvic examination are in order when evaluating for a VVF.
5. Imaging of the upper tract is important as 10% of VVF may have concomitant injury to the ureters.
6. Complex fistulas include radiation-induced fistula, previously failed fistula repairs, multiple fistulas, or those measuring greater than 2.5 cm.
7. Surgical repair is the mainstay of therapy for urinary tract fistulas.
8. Radiation induced or recurrent fistulas should be biopsied to exclude malignancy.
9. A transvaginal approach should be considered when attempting to repair the uncomplicated, or simple, VVF.
10. The general goal of fistula repair is to provide a tension free, water tight closure allowing for non-overlapping suture lines with multiple layers.
11. Tissue interposition grafts should be considered for complex fistula.

Introduction

The word "fistula" finds its roots in Latin, meaning pipe or tube, and as such is used to describe any abnormal communication in the body that allows for the aberrant passage of bodily fluids or feces. The incidence and etiology of fistula formation follows a geographic variance. In regions with ample access to health care, iatrogenic injury of the urothelium is the most common cause of urinary tract fisutlae. In countries where access to health care is a challenge, prolonged labor during the birthing process is often considered to be the leading culprit behind fistula formation (Fig. 12.1). Some studies suggest that in countries with limited access to health care, physicians not aptly trained in performing emergent cesarean section are often unable to execute these procedures, leading to prolonged labor and the complications associated with the prolonged labor complex, including subsequent fistula formation. In these countries death

is often associated with obstetric complications.[1] Improvement in obstetric care has seen a decrease in the incidence of fistulas, which can occur in up to 2% of obstetric cases.[2] Alternately fistulas may be congenital or arise in the setting of urinary obstruction, chronic inflammation, or malignancy. In rare cases, fistulas may even arise after traumatic intercourse and have been seen to manifest in victims of sexual assault earlier in the paragraph as noted.[3,4]

Regardless of the etiology, fistulas are often bothersome to the patient and may have a significant negative impact on his or her quality of life. This is particularly true if the patient suffers from continuous and uncontrolled leakage of urine. This also adds morbidity in terms of infections and degradation of the skin. Control and correction of urinary leakage helps minimize patient distress, and therefore prompt surgical intervention to repair the primary deficit is of paramount importance. Continence management devices such as pads, diapers, catheters, collection bags, or closed suction systems can be cumbersome and costly to the affected. Constant and compassionate reassurance and communication with the patient and a concerted effort to bring a timely resolution to the issue will assure the best possible outcome.

Vesicovaginal Fistula

ETIOLOGY

Vesicovaginal fistulas (VVFs) occur when there is an injury to the bladder, creating a communicating tract with the vagina eventually leading to seepage of urine. There are several implicating factors including infection, inflammation, and radiation as well as malignancies of the pelvic organs including colon, uterus, ovaries, and cervix. Surgical misadventure during routine operative interventions remains the most prominent perpetrator of urinary tract fistula. In the United States 90% of VVFs ensue after surgery.[1] The occurrence of trauma to the lower urinary tract during surgery for benign gynecologic conditions has been classically reported as high as 76% in some series; however, more recent studies have suggested this number is much lower and <1%.[5,6] There are approximately 240,000 hysterectomies performed in the United States on a yearly basis, although this trend is decreasing.[7] Systematic reviews on laparoscopic hysterectomies have shown the rate of injury to the genitourinary system to be 0.73%.[8] Untoward harm to the genitourinary tract may also occur during colorectal surgeries. The rate of injury to the genitourinary tract during colorectal surgeries is 0.18%.[9] Patients with preoperative exposure to radiation have been shown to have a higher incidence of surgical complications and worse prognoses.[9] In a study by Fujikawa et al. following 271 females receiving radiotherapy for cervical cancer, the authors noted that 8% of patients receiving pelvic radiation had a genitourinary complication arising from the treatment, and an additional 13.7% suffered complications associated with the rectum including fistula and bleeding.[10] The reported rate of iatrogenic injury to the urinary tract is likely under-reported, particularly in cases where routine intraoperative cystoscopy is not employed.[11]

There are over 300,000 procedures for pelvic organ prolapse (POP) and over 100,000 procedures for stress urinary incontinence (SUI) performed across the world every year.[12,13] A third of those patients with POP will require reintervention for recurrence of the prolapse.[12] Cases where the surgeon elects to use synthetic mesh material can present a risk for fistula formation and have been reported with both midurethral slings for SUI and slings used during sacrocolpopexy to correct POP.[14,15] The incidence of fistula formation from synthetic sling material used to correct SUI is low and reported across the medical literature as occurring in 0.1% of cases.[16] Erosion of foreign bodies into the vagina can occur after placement of synthetic mesh for POP or SUI as well as from retained objects introduced into the vagina such as pessaries or tampons that may find their way into the bladder over time (Fig. 12.2).

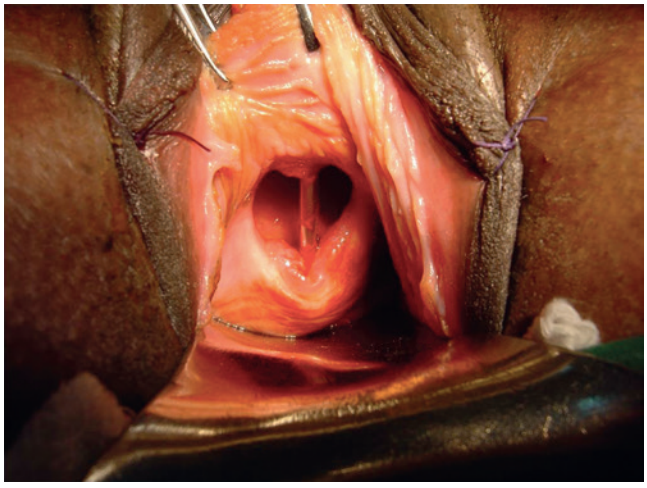


Figure 12.1 Vesicovaginal fistulas secondary to prolonged labor complex. (Photograph courtesy Dr. Andrew Browning.)

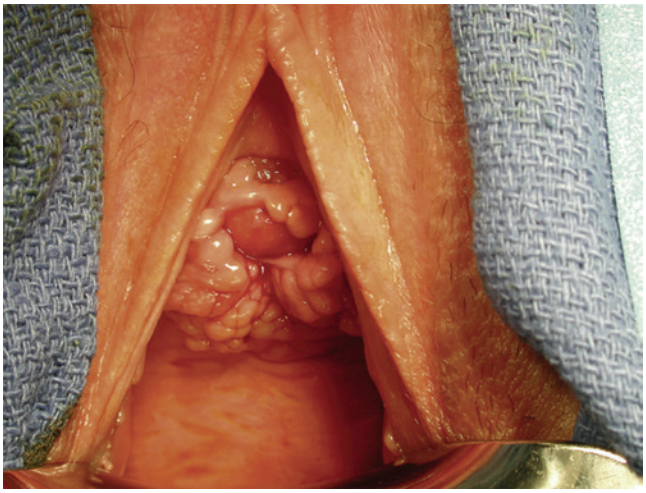


Figure 12.2 Urethrovaginal fistula associated with a midurethral synthetic sling. The urethra is exposed directly underneath the vaginal epithelium with no obvious periurethral fascia. The actual fistula (not seen) is located at the proximal border of the area where the vaginal epithelium meets the urethra. (From Nitti VW, Rosenblum N, Brucker BM. Vaginal Surgery for the Urologist. 1st ed. Philadelphia: Elsevier/Saunders; 2012:xvi.)

Meta-analysis of the global medical literature has suggested that the worldwide prevalence of urinary tract fistula is lower than suspected and reported to truly occur in 0.3% of all women. This value rises in women of reproductive age. There are regions of the world where the incidence is distinctly higher, including sub-Saharan Africa and South Asia where the prevalence is 1.5% and 1.6% respectively. The pooled incidence of vesicovaginal fistula in these countries in women that had recently given birth was 0.09%.[17]

PATHOPHYSIOLOGY

Iatrogenic fistula formation is thought to arise secondary to traumatic instrumentation or radiation along the genitourinary tract. The initial injury causes tissue ischemia. Eventually the affected area will undergo necrosis, and a fistulous communication will be formed with the genitourinary tract allowing for the aberrant passage of urine. The temporal relationship between the inciting event and actual leakage of urine is variable and can range from days, weeks, to even years after the traumatic incident. Delayed presentation of genitourinary manifestations is particularly notorious in patients undergoing pelvic radiation.[10] Ischemic microvascular damage arising secondary to obliterative endarteritis may take years to become apparent. A fistula that arises in the setting of prior radiation must raise suspicion for a possible malignancy and should be biopsied prior to surgical repair. The ischemic changes that caused the fistula may also compromise the surrounding tissue available for reconstruction. These repairs are challenging and are often with inferior outcomes.[18] In a fistula arising after surgery for malignancy, one must also exclude the possibility of a recurrence within the fistulous tract with a biopsy prior to surgery.

Any surgery in the vicinity of the genitourinary organs can lead to the formation of a fistula. Lacerations to the bladder if unrepaired will cause leakage of urine. A concomitant injury or opening in another pelvic structure raises the possibility of establishing a fistulous tract. The persistent output of urine production allows for the tract to persist by not allowing the injured tissue to heal. Once the fistulous tract is epithelialized it truly declares itself. Hysterectomy is a notorious culprit behind fistula formation particularly at the site of the vaginal cuff and along the anterior wall of the vagina. Fistulas can also form after retroperitoneal lymph node dissections, low anterior or abdominoperineal resections, or surgery to the uterus or cervix.

PRESENTATION

The clinical presentation of VVF is variable and highly dependent on the mechanism of injury to the bladder and vagina. Leakage of urine usually occurs within 1 week of catheter removal, although the presentation may be delayed. Patients that incur surgical injuries may develop signs and symptoms of peritonitis including fever, chills, vomiting, rebound, and guarding in the postoperative period suggesting the presence of a urinoma or possibly urinary ascites. A study in the prevention of fistula formation in women undergoing hysterectomies concludes that patients with abdominal pain and distention or paralytic ileus in the postoperative period should be assessed for trauma to the lower urinary tract. Hematuria or voiding symptoms such as frequency and urgency are also highly suggestive of injury to the bladder.[19] Often it is difficult to distinguish discharge after vaginal surgery from urinary leakage, and one must maintain a high index of suspicion for a fistula. The majority of patients with a VVF will declare themselves within a month of catheter removal with complaints of continuous leakage of urine per the vagina; however, the presentation may also be delayed. Very large fistulas may cause continuous or gravitational incontinence.

DIAGNOSIS

A targeted history and physical examination including a thorough pelvic examination are in order when evaluating for a VVF. A half speculum should be employed to assess all three vaginal compartments. In the acute setting there can be severe erythema and inflammation concealing the opening of the tract. Intraabdominal and vaginal collections of fluid may be sent for creatinine and urea measurements. A rectal examination should be considered to assess the posterior vaginal wall and rule out rectal involvement.[20] If digital rectal examination is suggestive of rectal involvement, proctoscopy should be performed.

Once a fistula is suspected, attention must be turned to promptly identifying the size and location, as this will dictate management. Imaging of the upper tract is mandated as 10% of VVFs may have concomitant injury to the ureters.[21] Historically this had been achieved with intravenous pyelograms. This has in great part been replaced by retrograde pyelograms and contrast-enhanced, cross-sectional imaging with a urographic phase, given its superior anatomic detail. Direct inspection of the fistulous tract with cystoscopy is important in its characterization. One can identify necrotic tissue of possible recurrence of malignancy that may alter management. Cystograms can also aid in visualization of the tract. Some fistulas are clearly evident and may be stented with a ureteral catheter or feeding tube for ease of resection. If the fistula is not clearly evident, any patch of erythema or bullous edema must raise suspicion as the offending site. A vaginoscopy may also be performed at the time of cystoscopy, adding minimal time to the procedure and enhancing diagnostic value.[22] If the upper tract has not been assessed or if the patient has a contraindication to intravenous contrast or cross-sectional imaging, retrograde pyelograms should be employed at the time of intraoperative cystoscopy (Figs. 12.3, 12.4).[23,24]

When there is doubt as to whether the discharge is urine or vaginal secretions, a "dye test" may be performed. A simple way to diagnose lower tract fistula is to fill the bladder with methylene blue and observe for leakage across the vaginal epithelium. If not clearly evident, the patient can insert a tampon and walk around the clinic to elicit leakage in the way it occurs naturally. If there is suspicion of an injury to the upper tract, phenazopyridine may be administered orally and a "double dye test" employed. The presence of the orange dye in the proximal tampon suggests a ureterovaginal fistula versus blue dye, a VVF. The presence of dye on the distal tampon may be indicative of leakage from the urethra, perhaps secondary to SUI. Urodynamic studies

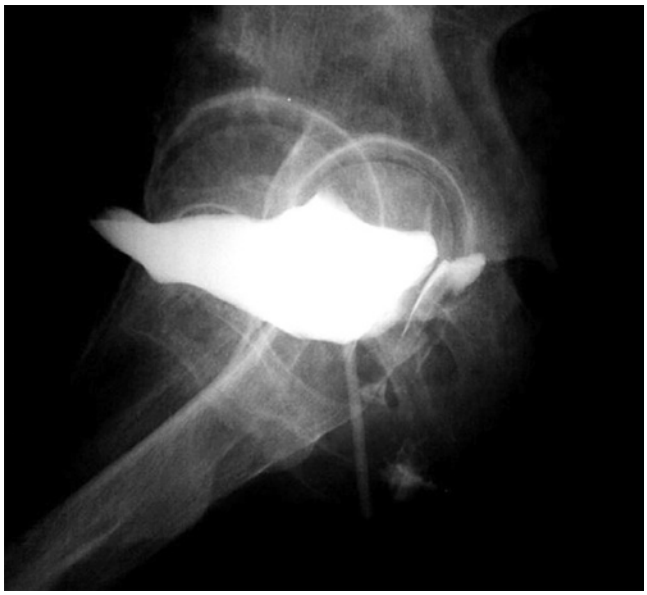


Figure 12.3 Cystogram demonstrating contrast in the vagina. (From Roslan M, et al. Suprapubic transvesical laparoendoscopic single-site surgery for vesicovaginal fistula repair: a case report. Wideochir Inne Tech Maloinwazyjne. 2012;7(4):307-10.)

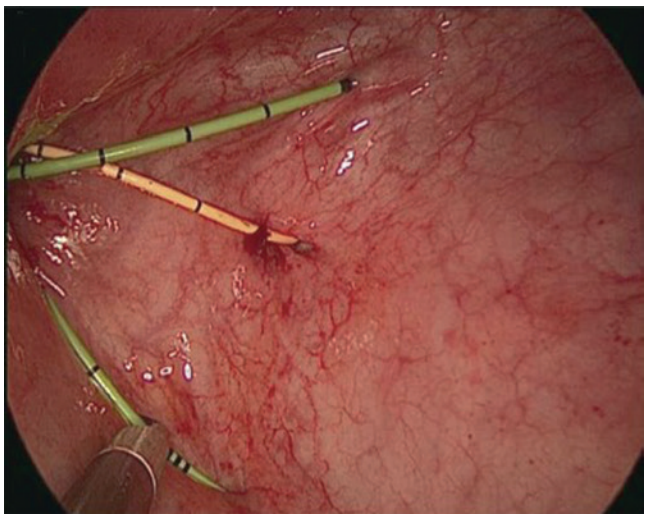


Figure 12.4 Catheterized ureters (green) and fistulous tract (yellow). (From Roslan M, et al. Suprapubic transvesical laparoendoscopic single-site surgery for vesicovaginal fistula repair: a case report. Wideochir Inne Tech Maloinwazyjne. 2012;7(4):307-10.)

may be of diagnostic value in the evaluation of a fistula, particularly if there is suspected concomitant storage or voiding dysfunction. Urodynamics allow for determination of capacity and compliance, which may be useful for patients that have been radiated. Videourodynamic testing has the added benefit of providing anatomic as well and functional information. Patients with injuries in the trigone or bladder neck are at risk for developing detrusor overactivity and SUI.[25] Patients that have received radiation may have decreased compliance and capacity as a consequence. Urodynamic studies may help plan for concomitant augmentation cystoplasty at the time of fistula repair or consideration of urinary diversion in severe cases (Box 12.1; Fig. 12.5).

Box 12.1 Diagnosis

History and physical examination including pelvic examination with half speculum
Cross-sectional imaging with excretory phase
Cystoscopy +/– vaginosocpy
Retrograde pyelogram
Dye test
Double dye test
Urodynamic testing (if concomitant VD)

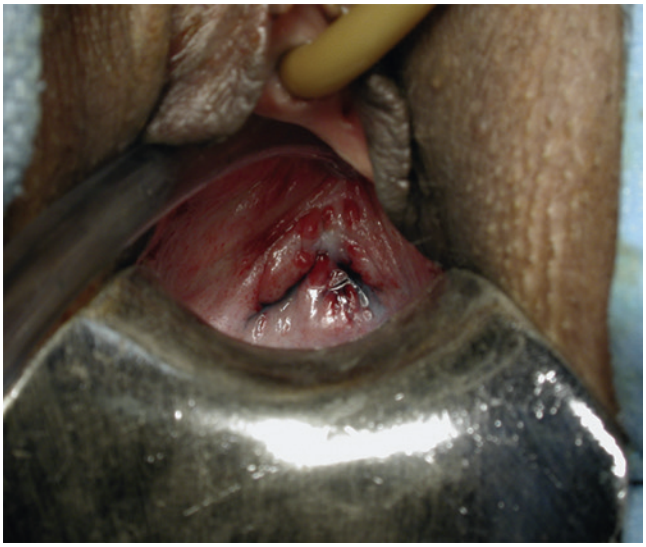


Figure 12.5 Instillation of indigo carmine in the bladder can help to locate the fistula. (From Nitti VW, Rosenblum N, Brucker BM. Vaginal Surgery for the Urologist. 1st ed. Female pelvic surgery video atlas series. Philadelphia: Elsevier/Saunders; 2012:xvi.)

PREVENTION

Vesicovaginal fistulas are largely a consequence of synchronous injury to the bladder and injury or incision of the vagina. This usually occurs after hysterectomy. The rate is highest after radical hysterectomy for malignancy and lowest following hysterectomy for pelvic organ prolapse.[6] Tissue is more prone to damage in patients with active malignancy or prior radiation. Injury to the bladder occurs during dissection from the cervix, especially when the procedure is complicated by prior radiation therapy, obesity, or prior surgery. Excessive fulguration and/or suture placement through the vaginal epithelium and into the bladder are notorious offenders. Prevention of VVF formation is contingent on proper surgical technique and postoperative urinary drainage. Using a Foley catheter during pelvic or vaginal surgery can help in identifying the bladder and maintains the bladder decompressed by allowing for adequate bladder drainage. The surgeon must maintain a high index of suspicion for injury, and in cases of suspected bladder or ureteral injury the urologist should be consulted at once.

Intraoperative use of cystoscopy should be employed whenever there is suspicion of bladder injury that is not readily identified. Studies suggest the combined used of cystoscopy and vaginoscopy can be of added benefit to identify

bladder injury.[22] The use of dyes and retrograde filling of the bladder, such as with dilute methylene blue, can also reveal an injury. The intravenous injection of indigo carmine can assist in the diagnosis of a ureteral injury. In the absence of indigo carmine, sodium fluorescein may be used to visualize the ureteral jets.[26] In some cases an intentional cystotomy is needed to ensure that the bladder is fully inspected and the ureteral orifices are identified. Whether from an endoscopic or open approach, ureteral support stents (i.e., open ended catheters, feeding tubes) can also be used to ensure patency of the distal ureter and serve as a referent point during bladder closure. Technical points in closing a bladder injury include watertight bladder anastomosis, tension-free repair, and in many cases, if possible, interposition of healthy tissue between the bladder repair and vaginal cuff closure.

Postoperatively, adequate urinary drainage should be accompanied by maximal detrusor relaxation induced by anticholinergic/antimuscarinic medication. In many cases a cystogram can be utilized prior to catheter removal to confirm integrity of the bladder. Any complaint of vaginal discharge before or after catheter removal should prompt evaluation. This would involve a complete history, and, if suspicious for recurrence or persistence of a VVF, a full vaginal examination (i.e., with a half speculum) is warranted. If the exam in the immediate postoperative period confirms persistence of a fistula, a longer period of bladder drainage is needed. Hypothetically, if a foreign body was identified (i.e., suture) one could consider removal in the early recovery period.

MANAGEMENT

Vesicovaginal fistulas can be categorized with a basic system of "simple," "intermediate," or "complex." Angioli et al. consider a singular fistula measuring less than 0.5 cm as "simple."[27] "Complex" fistulas include radiation-induced fistula, previously failed fistula repairs, multiple fistulas, or those measuring greater than 2.5 cm. These are often the result of chronic disease or radiation. Fistulas falling in the range of 0.5 to 2.5 cm in size are termed intermediate. For management purposes, intermediate fistulas are treated as complex fistulas (Table 12.1).

Simple fistulas may be amenable to conservative management, which includes bladder drainage, fulguration of the fistulous tract, and plugs with surgical glue.[28] Conservative treatment has been attempted in simple fistula 2 weeks to 2 months after injury, with success rates ranging from 0% to 100%. Retrospective studies have shown the best rate for spontaneous closure occurs with bladder drainage.[29] No prospective study has correlated the duration of drainage with the chance for spontaneous healing, and often this is based on personal experience. At best, one-fourth of small fistulas will close with prolonged catheter drainage.[27] Other conservative options for closure of VVFs include electrofulguration with or without injection of bovine collagen, fibrin glue, and/or autologous platelet rich plasma injection and platelet rich fibrin glue interposition.[30] The bladder is subsequently drained for 4 weeks. We find that these approaches have limited utility, are seldom effective, and are rarely employed. They are best reserved for nonsurgical candidates. Surgical repair remains the mainstay of therapy.

There are several caveats to ensure successful surgical correction of any fistula. One must confirm removal of any foreign bodies or necrotic tissue in the offending site. The surgeon must consider the need to extract the fistulous tract or whether to include it in the surgical reconstruction. In cases of fistula from a recent surgery, with low suspicion of malignancy a well-healed fistula track may provide strong tissue to anchor sutures. Meticulous dissection and visualization are important for the reconstruction of the genitourinary tract. Lesions near the ureteral orifice merit stenting of the ureter. The closure of the bladder and fistula site must aim to be watertight and tension free in multiple nonoverlapping layers. Interposition grafts are useful in complex, radiated, or recurrent cases.[31] The patient must be optimized for surgery. Infections must be cleared using targeted antimicrobial therapy. Atrophic vaginal epithelium in the postmenopausal woman should be fortified with topical estrogen replacement therapy preoperatively (Box 12.2).

Correct timing of the repair is imperative. Surgical repair should not be performed in the presence of active infection or significant inflammation. Conventional wisdom dictated a delayed repair with a 3- to 6-month "cooling-off" period to allow the fistula tract to mature and inflammatory process to subside. However, studies have shown that if a fistula is identified in the acute setting it may be treated successfully.[32] Zimmern et al. observed that surgical repair performed within 2 to 3 weeks of the injury had no increased morbidity or failure rates when compared with delayed repair. Contraindications to early closure include multiple unsuccessful closures, associated enteric fistula with pelvic phlegmon, and previous radiation. These types of fistulas are usually repaired after a 4- to 8-month waiting period.[20] Ultimately, the timing of surgery should be based on the

Table 12.1 Classification of Vesicovaginal Fistulas

Simple	Intermediate	Complex
Singular fistula	0.5 to 2.5 cm in diameter	Greater than 2.5 cm in diameter
Less than 0.5 cm in diameter		Radiation-induced fistula Multiple fistulas Previously failed fistula repairs

Box 12.2 Important Steps to Ensure Successful Vesicovaginal Fistulas Repair

Critical Steps for Successful Surgical Repair of Vesicovaginal Fistulas

- Removal of any foreign bodies or necrotic tissue
- Meticulous dissection and visualization of tissue planes
- Stent the ureter(s) if near the lesion
- Closure of the bladder and fistula site must be watertight and tension free
- Multiple nonoverlapping layers
- Interposition grafts in complex, radiated, or recurrent cases[31]
- Resolution of infectious/inflammatory process prior to surgical repair
- Atrophic vaginal epithelium should be fortified with topical estrogen replacement therapy preoperatively
- Patient must be optimized for surgery

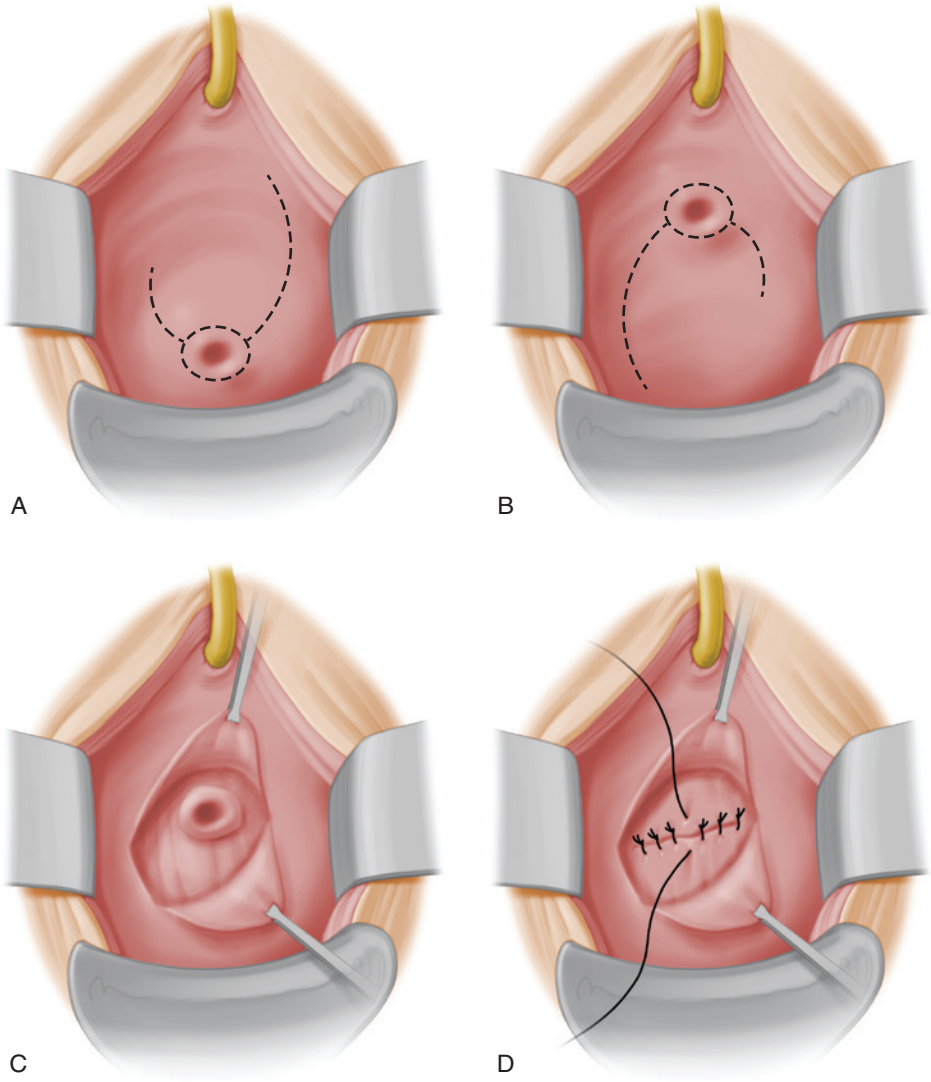


Figure 12.6 Incisions for vaginal flap repair of a vesicovaginal fistula. The configuration of the J incision will depend on the location of the fistula. A, For a more proximally located fistula, an anterior J is made. This allows for an anteriorly based flap. B, For a more distally located fistula, a posterior J is made to allow a posteriorly based flap to be mobilized. C, After mobilization of the vaginal wall, the fistula is fully exposed and ready for a two-layer closure. Ideally, there should be a distance of at least 1.0 to 1.5 cm from the fistula to the vaginal wall in all directions. D, Two-layer closure of the fistula. The deep layer is full thickness, including the bladder mucosa. The more superficial layer is an imbrication of the seromuscular wall of the bladder. (From Nitti VW, Rosenblum N, Brucker BM. Vaginal Surgery for the Urologist. 1st ed. Female pelvic surgery video atlas series. Philadelphia: Elsevier/Saunders; 2012:xvi.)

preference of the surgeon and the patient, and other factors involving the specific clinical scenario.

Convention had dictated an abdominal approach for supratrigonal fistulas, whereas a vaginal approach was used for infratrigonal, bladder neck, and proximal urethral fistulas. Current practice among experienced transvaginal surgeons is a vaginal approach in cases of VVF with a few exceptions. The advantages of a vaginal approach include patient comfort and recovery time.[20] It provides excellent exposure, access to multiple types of tissue interpositions, and the ability to perform multilayered closures without the morbidity associated with procedures that enter the abdominal cavity. Contraindications to a vaginal approach include severely indurated vaginal epithelium around the fistula, small capacity or poorly compliant bladder requiring augmentation, repair requiring ureteral reimplantation, involvement of other pelvic structures, vaginal stenosis, or the inability to obtain proper exposure[32].

An attempt should be made to repair the uncomplicated, or simple, fistula through the transvaginal approach (Fig. 12.6). This technique was refined by Dr. Raz.[33] The patient should be placed in dorsal lithotomy with care being taken to ensure protection of pressure points and adequate positioning. A cystoscopy is performed along with bilateral retrograde pyelograms if the upper tracts have not yet been assessed. An attempt should be made to catheterize the tract with a wire or conversely with a small Foley catheter or Fogarty catheter allowing for ease of dissection. A Foley catheter is inserted at the beginning of the case, the bladder is drained, and the catheter is clamped. Allis clamps and a ring retractor with sharp hooks are useful in retracting the vaginal epithelium ensuring adequate visualization for the

dissection. A vaginal flap is raised using the inverted "J" or "U" configuration to include the fistulous tract. It is useful to mobilize the vaginal epithelium away from the fistula. The margins of the fistula are trimmed and closed using absorbable sutures. The fistulous tract may be left or excised. Excision provides the advantage of eliminating the fibrous tract and closure of mucosa-to-mucosa. The disadvantage is increasing the size of the repair. If the bladder is friable it may not hold stitches well. The fistulous tract provides tensile strength to the closure. The perivesical fascia is then closed with absorbable sutures in a perpendicular fashion (over the fistula tract), with the edges inverted. The bladder is filled with fluid or diluted methylene blue dye at this point to check for a watertight closure. At this point if a flap is needed it would be used to cover the repair. Finally, the vaginal wall is closed in a third layer, in a nonoverlapping absorbable suture line. A suprapubic tube and/or a Foley catheter are left for straight drainage, and anticholinergic/antimuscarinic medications are given liberally.[34] Not all surgeons elect to leave two catheters in place postoperatively. A cystogram is performed 10–14 days postoperatively; if no extravasation is evident, the Foley and suprapubic catheters are sequentially removed. Refractory cases or those with fistulas near or at the vaginal cuff in patients that do not wish to preserve sexual function may be treated with obliterative procedures (Fig. 12.7). In cases where the uterus is present a partial colpocleisis, such as the Latzko repair, will achieve closure of the fistula and vaginal canal while preserving the uterus. A 3- to 4-cm elliptical segment of the vaginal epithelium is excised on the anterior and posterior portion of the prolapsed vaginal wall. Linear sutures are then placed to invert the bladder wall while avoiding the bladder lumen. Further layers continue to invert the bladder wall. The vaginal wall is then closed with a running suture. A benefit of this procedure is that it requires minimal resection, as the vaginal space is obliterated.

Fistulas associated with mesh complications or radiation, or complex fistulas will require the use of tissue interposition grafts. Nonoverlapping suture lines in the vaginal and vesical repair ensure a successful reconstruction. The well-vascularized adipose tissue in the labia majora provides a supple graft for distal fistulas. A peritoneal flap may be harvested for a fistula high in the vaginal vault, particularly if there is a fresh closure of the vaginal cuff. The selection of autologous tissue depends on the size of the fistula, its location, the quality of patient tissues, and the surgeon's preference. The bulbocavernosal fat, or Martius flap, is reliable, but it requires a separate incision. The pedicle originates from the posterior labial artery, a branch of the internal pudendal artery. The Martius flap may not reach fistulas high in the vaginal vault. The vagina may be shortened during attempts to extend the flap from the labia to the vagina. Peritoneum is an excellent substitute in these high fistulas; however, it can be challenging to mobilize to the lower vagina. The peritoneal flap is well vascularized and readily available, can be done with an open or closed peritoneum, and can be harvested with no additional incision.[34] Patients that have devastating fistulas that require complex vaginal repairs can be treated with a Singapore flap. This is a fasciocutnaeous flap with a pedicle that is supplied by the pudendal artery. One can rotate the graft superior and medially to reconstruct the vaginal canal (Fig. 12.8).

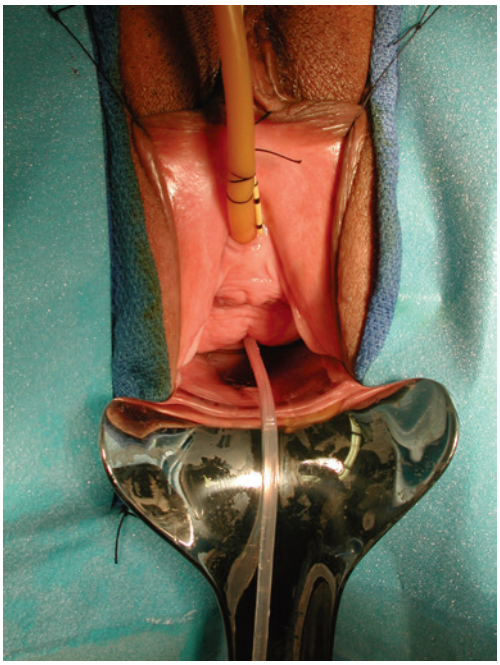


Figure 12.7 A vesicovaginal fistula located near the vaginal cuff has been catheterized with a small Foley catheter. Traction on the Foley catheter allows easy exposure and dissection. (From Nitti, V.W., N. Rosenblum, and B.M. Brucker, *Vaginal surgery for the urologist*. 1st ed. Female pelvic surgery video atlas series. 2012, Philadelphia: Elsevier/Saunders. xvi, 200 p.)

When the Martius flap fails or in the case of a larger fistula as associated with obstructive labor, there are adjuvant flaps and techniques in the armamentarium of the reconstructive urologist. Techniques include the use of vaginal wall flaps, omental flaps, biologic patches, and muscle flaps. In a series of patients with complex urethrovaginal fistulas (UVFs) that were refractory to anatomic repair with Martius interposition flap, Bruce and colleagues used rectus abdominus flaps based on the inferior epigastric artery to successfully treat 83% of their patients. These flaps are not only useful as interposition flaps but also have been proposed to fortify the bladder neck in cases of intrinsic sphincter deficiency.[35] The rectus flap has the advantage of being the least deforming to the exterior appearance of the patient. Similar techniques have been described using the gracilis muscle.[36] In cases where the urethra is completely obliterated, tubularized bladder wall flaps and/or vaginal wall flaps are used to create a neourethra. An autologous fascial sling is then placed to reestablish the continence mechanism.[37]

An open abdominal approach may be considered for complicated fistulas, previous failed repairs, a narrowed or stenotic vagina, those in close proximity to the ureters, or when concomitant procedures are being considered, such as ureteral reimplant or bladder augmentation.[38] Further, if the surgeon is not well versed in vaginal surgery or is more comfortable with the abdominal approach, it is reasonable to perform the surgery with the probability of the best outcome. Abdominal surgery allows for harvesting of omentum, which serves as a supple interposition graft

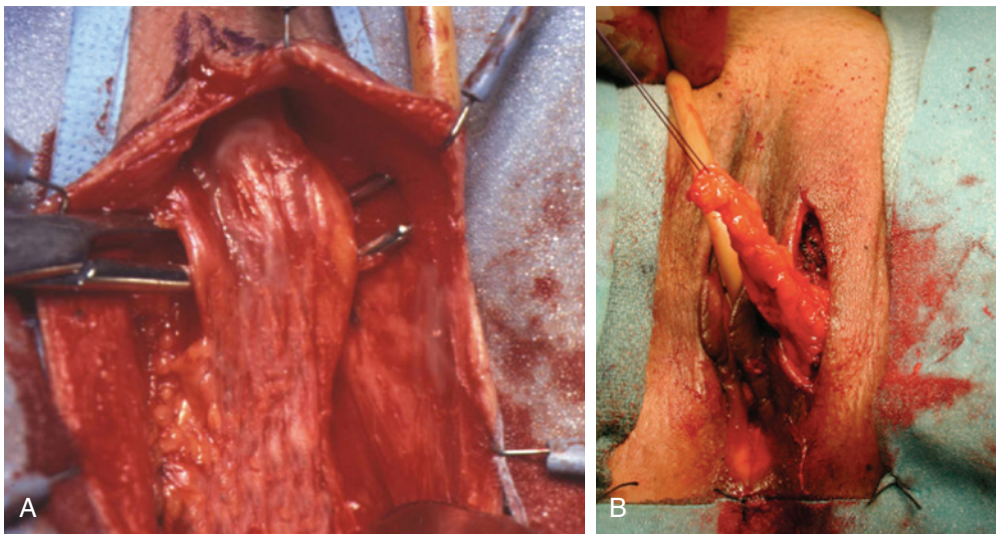


Figure 12.8 A, A Martius flap can be mobilized by making a longitudinal incision over the labia majora or in the crease between the labia minora and majora. Just underneath the skin is an avascular plane that sits between the skin and the underlying fat pad. B, In this case the flap is based on the blood supply from the inferior pudendal artery. The flap has been mobilized off the pubic bone and can now be tunneled under the labia minora and vaginal epithelium. (From Nitti, V.W., N. Rosenblum, and B.M. Brucker, *Vaginal surgery for the urologist*. 1st ed. Female pelvic surgery video atlas series. 2012, Philadelphia: Elsevier/Saunders. xvi, 200p.)

for the repair. A laparotomy does have the advantage of excellent exposure and visualization of the fistulous tract; however, it is at the expense of higher complications and the prolonged convalescence associated with abdominal surgery. Patients with abdominal repair also require longer hospitalizations when compared to transvaginal repairs.[39] An abdominal surgery approach may be extraperitoneal or transperitoneal, as well as extravesical or transvesical. The classic approach as described by O'Connor and Sokol entails a transabdominal transvescial repair where the bladder is bivalved to the fistulous tract. The vaginal wall is dissected off the bladder, and the fistulous tract is closed on both ends. An omental or peritoneal flap is placed in between the bladder and vaginal wall to prevent recurrence.[40] The incidence of bladder spasms is usually more pronounced following abdominal repairs and the standard use of a suprapubic tube. Urethral catheters and anticholinergics/antimuscarinics are maintained until a voiding cystourethrogram is performed 2–3 weeks postoperatively.[34] In severely refractory cases one may consider the use of urinary diversion. This has been found useful in patients with multiple failed attempts, patients with extensive radiation, or very large soft tissue defects. One may consider a continent pouch (i.e., Indiana pouch) versus an incontinent diversion (i.e., ileal conduit); however, orthotopic neobladders (i.e., Studer) are usually not employed.

Advances in minimally invasive techniques have seen a rise in the surgical repairs approached via pure laparoscopy or with robotic assistance. While this technology is still being developed and refined, successful outcomes have been reported. There were some initial difficulties maintaining pneumoperitoneum, but this has been overcome with the use of a vaginal packing and placing the Foley to mild traction.[38] In a comparative analysis of outcome between open and robotic surgical repair of recurrent supratrigonal VVF, Gupta et al. noted similar outcomes in terms of fistula resolution, exceeding 90% in both groups. Surgical complications such as blood loss and hospital stay were less in the robotic versus open group. They concluded that due to the decreased morbidity of the robotic over open approach, a transabdominal robotic repair should be considered in refractory cases.[41] The vaginal approach, however, may still remain the truly most minimally invasive approach, but does require a unique skill set.

The success rate of VVF repairs appears to be independent of the surgical approach, as long as the surgeon ensures a watertight repair with nonoverlapping suture lines and the use of interposition flaps as needed. In the absence of infection, inflammation, or previous radiation there is no additional benefit to delay of the surgical repair if the injury is recognized early in the postoperative period. This also minimizes the patient's distress and discomfort. The ideal timing of repair is at the time of injury.[42] The success rates of repairs are equivalent for the abdominal and vaginal approach and in most series exceed 80–90%.[32] Fistulas in radiated patients and those with prior failed repairs have inferior results; patients must therefore be counseled adequately. These patients can be treated temporarily with urinary diversion. This allows for tissue healing and resolution of inflammatory processes. Healing can occur and large defects may decrease in size and granulate. Primary closure at times can be achieved using interposition grafts or muscle flaps. Some patients that persist with urinary leakage, even after successful fistula repair, may call for a permanent urinary diversion.[43]

Urethrovaginal Fistula

ETIOLOGY

Cephalopelvic disproportion during prolonged vaginal delivery can lead to a prolonged and obstructive labor. Ischemia secondary to compression of the vaginal epithelium,

urethra, detrusor, and bladder mucosa can create such an injury. The principal causes of dystocia are problems with the birth canal, a large baby, or a small pelvis. Some studies have supported this claim by noting that fistula formation as well as obstructed labor is more common in primiparous mothers of male offspring due males' larger circumference.[44] Pressure on the symphysis pubis with forceps may also cause these injuries.

When there are injuries secondary to dystocia, one must address more than just the area of the fistula itself, as the affected field usually extends beyond the hiatus. Patients may suffer from urethral loss, stress incontinence, rectovaginal fistula formation, anal sphincter incompetence, and foot drop. In addition to their physical injuries, women who have experienced prolonged obstructed labor often develop serious social problems, including divorce, exclusion from religious activities, separation from their families, worsening poverty, malnutrition, and unendurable suffering.[45]

As with VVF, in the industrialized world, the most common cause of urethrovaginal fistula (UVF) formation is iatrogenic injury. Surgical procedures in the vicinity of the urethra pose the highest risk. Surgical repair of urethral diverticulum and anterior colporrhaphy constitute 15% and 45% of these injuries, respectively.[34] While uncommon, cases have been reported of urethrovaginal fistula from traumatic catheterization. Other causes include bladder neck suspensions and anti-incontinence surgeries as well as malignancy and radiotherapy (Table 12.2).

Midurethral sling procedures pose a particular risk due to the sheer volume of these procedures performed on a yearly basis.[46] Reports have estimated the prevalence of urinary incontinence in women between 30 and 60 years old to be 30%.[47] Any laceration or thermal injury during dissection increases the possibility of subsequently developing a fistula. The risk of developing a fistula during a sling procedure for SUI is cited at 1%.[48] This risk may increase in patients with preexisting microvascular damage such as diabetes or radiation therapy. When there is concomitant injury to the urethra during placement of a synthetic midurethral sling, one should repair the urethra primarily and abort placement of the mesh. In cases where there is concomitant SUI at the time of fistula repair, one can always consider an autologous fascial pubovaginal sling as the use of synthetic mesh is contraindicated.

PRESENTATION

The clinical presentation of urethrovaginal fistulas is dependent on their size, location, and relation to the urethral sphincter. Fistulas proximal to the urinary sphincter may be associated with complaints of SUI or, if close to the bladder neck, could cause continuous leakage of urine. Patients may present with vaginal pain or recurrent urinary tract infections.[49] Vaginal pooling of urine can also be a complaint and lead to skin irritation and breakdown. This may lead to recurrent yeast infections or candidiasis. Patients with distal fistulas may be completely asymptomatic or present with split urinary stream and/or dribbling. Very large fistulas can also cause continuous or gravitational incontinence.

As with VVF the timing of presentation can be varied and depends greatly on the mechanism of action behind the inciting injury. Obstetric trauma usually manifests within a few days of the injury or removal of the Foley catheter. The majority of iatrogenic fistulas will declare themselves within a month of surgery or catheter removal. Urethrovaginal fistulas secondary to radiotherapy for malignancy may have a delayed presentation from months to years and include symptoms such as hematuria and recurrent infections.[50]

Table 12.2 Most Common Causes of Urethrovaginal Fistula

Industrialized World	Nonindustrialized World
Iatrogenic injury	Prolonged labor complex

DIAGNOSIS

When there is a suspicion of a fistula the standard evaluation should begin with a thorough history and physical examination. Direct visual interrogation of the urethra with the cystoscope allows for a comprehensive assessment of its luminal aspect. Visual inspection of the vagina should note areas of erythema or inflammation. Validated lower urinary tract questionnaires allow for standardized follow-up of bothersome symptoms.[51] It is important to exclude coexisting injuries such as vesicovaginal and ureterovaginal fistula. An in-office "double dye" test and/or retrograde pyelogram at the time of repair can aid in dismissing these pathologies. Voiding cystourethrograms may be helpful in establishing the diagnosis and excluding others. Fistulas in the setting of previous pelvic malignancy or radiation should be biopsied prior to repair to exclude tumor growth. Urodynamic testing can be used to assess the capacity of the bladder and ensure adequate compliance. It can also assess for the presence of other causes of incontinence when trying to diagnose a fistula. Findings such as detrusor overactivity incontinence or stress incontinence can mimic symptoms of a fistula or can be concomitant diagnoses that need to be managed. If the mechanism of injury (e.g., pelvic fracture, recent radical pelvic surgery) suggests more global lower urinary tract dysfunction associated with a urethral injury, the ability of urodynamics to assess detrusor function can be useful. However, starting with a noninvasive test such as uroflow and postvoid residual may be sufficient to rule out significant dysfunction. Particularly important in the diagnosis, and ultimate management, of urethral vaginal fistula is the presence or absence of incontinence and the presence or absence or obstruction (i.e., UVF from midurethral sling). In cases of incontinence the clinician may be much more likely to suggests a concomitant autologous sling (i.e., fascia lata or rectus fascia). If obstruction is seen, more aggressive sling take down or urethrolysis may be advisable. The fluoroscopic image from video urodynamics can confirm the level of continence at the bladder neck, explain the variability of symptoms, and influence the postoperative catheter management.

MANAGEMENT

The correction of urethrovaginal fistulas is a challenge and poses a particular set of problems for the surgeon in order

to achieve a watertight, tension-free, multilayer closure. Their distal location makes harvesting local tissue for interposition flaps difficult. The inciting factors usually lead to extensive defects with significant periurethral scarring and fibrosis leading to difficult resections. This can lead to fascial defects that may compromise creating a repair with multiple layers.[52] The patient must be optimized for surgery, clearing infections with appropriate antibiotic therapy, and the atrophic vaginal epithelium in the postmenopausal woman should be fortified with topical estrogen replacement therapy to ensure optimal tissue quality at the time of repair.

Several factors must be considered at the time of the surgical intervention. All inflamed and erythematous tissue should be debrided and sent to pathology for microscopic examination, especially in the setting of recurrent fistulas, malignancy, or previous radiation. Foreign bodies present such as a synthetic mesh must be removed in their entirety as these may predispose to fistula recurrence.[49] Devitalized tissue must be excised to ensure margins with viable tissue that is adequate for the final closure. Distal fistulas in asymptomatic patients that do not have voiding complaints may be safely observed. Alternatively, these lesions may be eliminated by spatulating the meatus down to the fistulous tract.[53] Proximal and large lesions may require extensive dissection, and often the urinary sphincter mechanism is compromised. Patients must be adequately counseled preoperatively of the possibility that SUI may develop after their repair. Successful anatomic repair may lead to the development of SUI or obstructed voiding in up to 50% of patients. Conversely all synthetic mesh should be removed during fistula repair, which may result in the propagation of SUI.[50] One study following 71 women after urethrovaginal fistula repair reported 52% of the patients developed postoperative SUI.[54] These patients were treated with autologous pubovaginal slings or synthetic slings. Patients at risk for developing SUI and patients with existing SUI may be offered concomitant treatment with autologous sling (i.e., pubovaginal slings using rectus fascia or fascia lata). The use of synthetic mesh is contraindicated at the time of fistula repair.

The positioning of the patient and instruments used to achieve adequate exposure for repairs of a urethrovaginal fistula are the same as for a VVF with the exception of including a urethroplasty set with fine, sharp dissecting instruments. The timing of the repair follows the same line of reasoning as with VVF. Fistulas that are not infected or present in the setting of radiation may be repaired in the acute setting successfully. The procedure should commence with a cystoscopy and an attempt to catheterize the fistulous tract with a wire of feeding tube. The Foley catheter is inserted and the bladder is drained. An inverted J or U incision is made and a vaginal flap is raised to include the fistula tract. Dissection is carried out to the periurethral fascia surrounding the fistula, and it is carefully incised. The edges of the tract are refreshed, and the fistula is closed with absorbable sutures. The periurethral fascia is closed in a perpendicular fashion to avoid suture overlap. The ureteral caliber needs to be considered for large defects. Other reconstructive techniques may be needed if the repair would result in a significant narrowing. Vaginal flaps and anatomic repairs have a higher failure rate when compared to using pedicle-based interposition flaps.[55] The bulbocavernosal fat from the labia may be harvested and interposed over the repair at this time. The vaginal epithelium is approximated to include the previous site of the fistula.

Once the reconstruction is complete the surgeon may consider placement of a suprapubic tube (SPT) in complex or difficult repairs. This allows for quicker removal of the urethral catheter and does not keep the bladder neck open allowing for the repair to heal free of urine finding its way around the catheter. If an SPT is to be placed, the decision should be made prior to reconstruction of the urethra, as one should avoid passing the cystoscope over a fresh repair. Patients with SUI, or when a fascial sling is used to reinforce a repair, also benefit from SPT placement as this would also avoid the need to catheterize over a fresh repair if the patient experiences urinary retention.

The cystotomy should be made under direct visualization with the cystoscope and a Foley catheter left to drain the bladder. The length of catheter use depends on the complexity and location of the repair. Anticholinergic/antimuscarinic medication should be used liberally, and the surgeon may choose to discontinue prior to performing voiding cystourethrogram (VCUG). If no extravasation is noted the urethral catheter is removed and the suprapubic tube is clamped and sequentially removed. If there is evidence of extravasation, the surgeon has the option of replacing the uretheral catheter with care not to injure the repair. The suprapubic tube would be left for drainage. The VCUG is then repeated in 1–2 weeks. When autologous pubovaginal slings are used, the harvesting of the sling and passing of needles into the retropubic space are performed at the beginning of the case. This avoids passing the cystoscope over the newly reconstructed urethra. Occasionally, a urethral catheter is avoided to prevent ischemia or pressure on the repair, especially in the case of middle or distal urethrovaginal fistulas.[34]

Ureteral Fistula

Ureteral fistula comprised 10% of genitourinary fistulas treated in a recent 8-year case series from a tertiary referral center.[56] They have been reported in 2–3% of laparoscopic hysterectomies[8,57] and in 4.5% of 6000 obstetric or gynecologic surgeries in a multinational study conducted in the developing world.[58] Ureteral fistula can involve any neighboring organ, most commonly the vagina, but fistulous connections with abdominal or pelvic vasculature, bowel, skin, and cervix have been described.[59] An understanding of ureteral fistula is important given their significant propensity for upper tract injury and the possibility of morbidity due to a missed diagnosis.

ETIOLOGY

As described in our discussion of VVFs, ureteral fistulas generally arise from ischemic necrosis, leading to urinary extravasation creating an inflammatory condition that induces the fistulous connection to form. Fistulas may also form after unrecognized injury of the ureter. Sequentially, ascending and descending branches from the renal and gonadal arteries and the aorta supply the ureter with

overlapping segments that protect the ureter from ischemia. However, the delicate terminal branches run along the adventitia of the ureter and are vulnerable to intraoperative avulsion, injury, and occlusion. Consequently, when possible surgical practice should involve minimizing the use of a clamp on the ureter and traumatic grasping of the ureter. Manipulation needs to be done carefully and with understanding of the delicate vasculature.

Iatrogenic injury is by far the most common cause of ureteral devascularization and ischemia; by comparison, patient series from the busiest trauma centers only report 10 ureteral injuries per year, a fraction of which result in fistulas.[60] From 52% to 82% of iatrogenic ureteral injuries are estimated to occur during gynecologic surgery[61] with the remainder occurring during abdominal pelvic surgeries – specifically obstetric, urologic, colorectal, or vascular surgery – or following radiation therapy. Complications, such as ureteral transection, ligation, puncture, or crushing, occur in 0.05% to 30% of such cases, depending on surgeon expertise, patient factors, and the technical difficulty of the procedure.[60] A recent systematic review of urinary tract injury in benign gynecologic surgeries found a ureteral injury rate of 0.3%, compared to a 0.8% bladder injury rate.[62] Ureteral injuries are missed at the time of the initial surgery in 33% to nearly 90% of cases in reported series.[61]

Early management of the injury may decrease the likelihood of fistula formation.[8,61] Patients with early postoperative findings, such as anuria, urinary ascites, or hydronephrosis, will require workup and subsequent diagnosis of the cause and should be evaluated for ureteral injury; this early recognition and subsequent management may decrease their risk of ureteral fistula formation. However, many ureteral injuries are difficult or impossible to diagnose intraoperatively, such as thermal injury or devascularization. These types of insults may present later than things like cut injuries, avulsions, etc. Ureteral fistulas due to intrinsic patient risk factors alone are rare, but have been reported in trauma and oncology literature.[61,63] More commonly, risk factors predispose patients to have a ureteral injury go unrecognized by increasing the difficulty of the surgical intervention or by contributing to poor wound healing; such factors include obesity, diabetes, chronic inflammation, endometriosis, prior surgeries, and radiation (Box 12.3).

Ureterovaginal fistulas are the most common ureteral fistulas. They typically form following an undiagnosed ureteral injury during hysterectomy if the ureter is inadvertently clamped or ligated in an attempt to control bleeding from the uterine artery. More broadly, the complex pelvic anatomy surrounding the distal third of the ureter and its proximity to the vagina and uterus pose a notable risk in any female pelvic surgery, such as hysterectomy, cesarean section, low anterior resection, and abdominal perineal resection of the colon. The incidence of ureteral injuries during hysterectomy initially increased with the introduction of laparoscopic techniques; however, this rate appears to be decreasing with the increased adoption of robotic surgery.[34] This has been attributed to the improved visualization afforded by robotic assistance and to surgeons' increased familiarity with the minimally invasive approach to this surgery.[64]

Ureteroarterial fistulas (UAFs) are rare, with 118 reported cases identified in a recent review.[65] Women are 50% more likely to be affected. Overall, they are associated with 10–38% mortality. Fistulas involve the aorta in 1.6% of cases; however, these fistulas are universally fatal if not diagnosed and treated. The common iliac (60%) and external iliac (20%) arteries were most likely involved in patients with no history of urinary diversion. Chronic ureteral stents are a significant risk factor for UAFs, with 74% of patients known to have a history of stenting. Radiation, pelvic cancers (bladder, cervical, and colorectal), and vascular disease are also risk factors for UAFs.[65,66]

Ureteroenteric fistulas (UEFs) comprise about 1% of urinary tract fistulas[67] and usually involve the duodenum. Penetrating trauma and iatrogenic injury are the most common etiologies of UEF, but very often they result from chronic inflammation of the ureter or intestines by medical disease or foreign bodies (ureteral calculi or ingested objects).[68,69] Radiation therapy and malignancy have also been reported as causes of UEFs.[67]

Box 12.3 Factors That Affect Wound Healing

Obesity
Diabetes
Chronic inflammation
History of radiation
Prior surgeries

PRESENTATION

Ureterovaginal fistulas typically present as persistent urinary incontinence. This can often be difficult to differentiate from VVFs at initial presentation, as both entities present approximately 1–4 weeks after surgery with continuous leakage.[56,70] Ureteral violation, such as ureterotomy or avulsion, leads to more immediate fistula formation than do ischemic insults from crush injury or radiation. This is related to the pathologic process of necrosis and the initial absence of an inflammatory reaction to extravasated urine. Some UVFs occur secondary to ureteral stricture, which also results in a prolonged interval to presentation. A careful history can distinguish between the unchanged voiding patterns in UVF from the decreased voiding per urethra in significant VVF.[71] The description of flank pain should increase suspicion of ureteral involvement. Associated pathology contributes additional symptoms, such as abdominal pain and ileus with urinoma formation, lower urinary tract symptoms with cystitis, or systemic illness and flank pain with pyelonephritis.

Ureteroarterial fistulas universally present with painless hematuria, ranging from microhematuria to hemorrhage, with hemodynamic instability seen in 17.8% of patients, due to the size of the fistulas and the involved vessels. Hematuria may be intermittent. In 13.5% of cases, this is precipitated by stent change; in most cases, some precipitating event is found.[65] Patients with ureteroenteric fistulas clinically present with recurrent UTIs and pneumaturia. Cultures typically demonstrate enteric flora. Patients may be systemically ill, but not necessarily.

DIAGNOSIS

Evaluation for UVF should include evaluation for concomitant VVF, as discussed earlier in this chapter. Physical examination can be useful in ruling out alternative etiologies. Some clinicians find the double dye test useful to distinguish between vaginal and ureteral fistulas.[70] The presence of the orange dye in the proximal tampon suggests a ureterovaginal fistula; blue dye suggests a VVF. Laboratory analyses should include serum creatinine and blood urea nitrogen (BUN), which may be elevated due to absorption if there is urine leaking into the peritoneal cavity, in addition to urine studies. A complete blood count and inflammatory markers may also be useful in the patient with symptoms concerning for infection. In order to ensure adequate evaluation of the ureters, we favor computed tomography (CT) of the abdomen and pelvic with and without contrast, including delayed excretory phase for ureteral opacification as well as a full assessment of the peritoneum and both kidneys.[61,72] The clinical history should be provided to the radiologist so that the study can be tailored to the clinical question. In some cases with concomitant ureteral obstruction additional delayed imaging may be needed. Magnetic resonance imaging (MRI) can also provide a cross-sectional representation of a UVF and superior soft tissue contrast, which is especially useful in patients with pelvic malignancy.[73] Intravenous pyelograms and retrograde ureterograms can be used to identify urinary extravasation; however, positive findings may still require further investigation with CT or MRI studies for more complete delineation of the ureter and adjacent structures.[60] Ultrasound can identify hydronephrosis and large fluid collections, which will lead the clinician to obtain other diagnostic tests but may fall short of identifying small urinomas or any specific ureteral pathology. Doppler also can be used to look for ureteral jets to suggest patency of the ureter. Ultrasound alone is limited in its utility and it is not recommended for the definitive diagnosis of ureteral injuries.[72]

The most critical tool in diagnosis of ureteroarterial fistulas is a high degree of clinical suspicion.[74] Patients with gross hematuria with risk factors for UAF, such as chronic ureteral stents or advanced abdominopelvic malignancy, may benefit from emergent workup of hematuria, rather than the standard elective outpatient workup. Cystoscopy can localize hematuria to a specific ureter with visualization of bloody efflux.[75] Extravasation from a UAF is not typically seen on standard upper tract imaging, as the ureter is often occluded by blood products, but remains useful in ruling out renal or other ureteral pathology.[65,74,76] Ureteroscopy is not recommended given the potential for instigating a large-volume bleed.[75] Angiography is the present standard of care for diagnosis of ureteral fistulas.[65] It is also a potentially therapeutic test; if the ureter is opacified, the fistulous connection can be embolized, as we will discuss later in this chapter. The sensitivity of angiography has been estimated to be between 50% and 69%.[77,78] This can be increased with provocative maneuvers to dislodge clots; however, this has inherent risks of brisk blood loss and should only be attempted in a controlled setting with the ability to rapidly occlude the fistula or to proceed to operative exploration.[75]

Ureteroenteric fistulas are diagnosed with CT with late excretory phase contrast in most of the cases in the literature. This is more reliable than opacifying the intestinal tract given the high transit time and low-pressure system as compared to the urinary system.[79]

PREVENTION

The mainstays of prevention of ureterovaginal fistulas remain a thorough knowledge of anatomy, avoidance of ureteral vascular supply, and caution during hemostatic control.[80] Should ureteral injury occur, intraoperative recognition allows for prompt evaluation, possibly repair with stenting, and may decrease the likelihood of fistula formation.[60] This is not always feasible in surgeries complicated by significant blood loss, or aberrant anatomy from malignancy, radiation, or prior surgeries. Ureteral stent placement has been suggested to aid in preventing ureteral injury, but there does not appear to be a decrease in the incidence of ureteral injury with this technique.[70] The added operative time, risk, and morbidity must then be weighed against the chance of recognizing an intraoperative injury.[60]

The risk of UVF can be minimized by limiting long-term use of ureteral stents, especially in patients with other risk factors for fistula formation.[65] Avoiding ureteroenteric fistula is best accomplished by addressing the underlying disease processes.[68]

MANAGEMENT

After diagnosis of a ureterovaginal fistula, the priority is achieving adequate drainage of the urinary system.[60,81] While there have been reports of spontaneous closing of UVF with urinary diversion,[82] it requires a narrow set of circumstances and is not an option in many cases. If the ureter appears to remain in continuity on imaging, a retrograde ureteral stent can be placed. Ureteral patency and anatomy should be confirmed intraoperatively with a retrograde pyelogram prior to stent placement.[60] If this is not possible, anterograde drainage with a nephrostomy tube can be attempted. This may also allow for attempted anterograde ureteral stent placement if the clinical scenario warrants. Ureteral stent placement in patients with favorable anatomy and a small fistula has been reported to successfully treat the fistula, with the largest series reporting 71% success at 1 year[56,83,84] after stent placement for 6 weeks.[85]

In many cases, operative repair may ultimately be needed. Repair would be indicated, for example, if stenting was not possible, there was persistence of the fistula after stenting, other concomitant fistulas needed surgical repair, or there was an associated finding like a large structure that was going to require intervention. Care must be taken to eradicate infection, nutritionally optimize the patient, and, in some cases, rule out an occult malignancy. Historically, repair was delayed for 3–6 months, but recent studies have shown no difference in outcomes for earlier repair in uncomplicated patients.[86] Repair is often delayed for at least 6 weeks to allow full delineation of the diseased ureter.[71] In a radiated patient, additional time to repair is prudent given the slow appearance of injury, which is usually about 6 months. An indwelling nephroureteral stent or an internal ureteral stent can result in periureteral inflammation, and some would advocate removal for several weeks prior to repair.

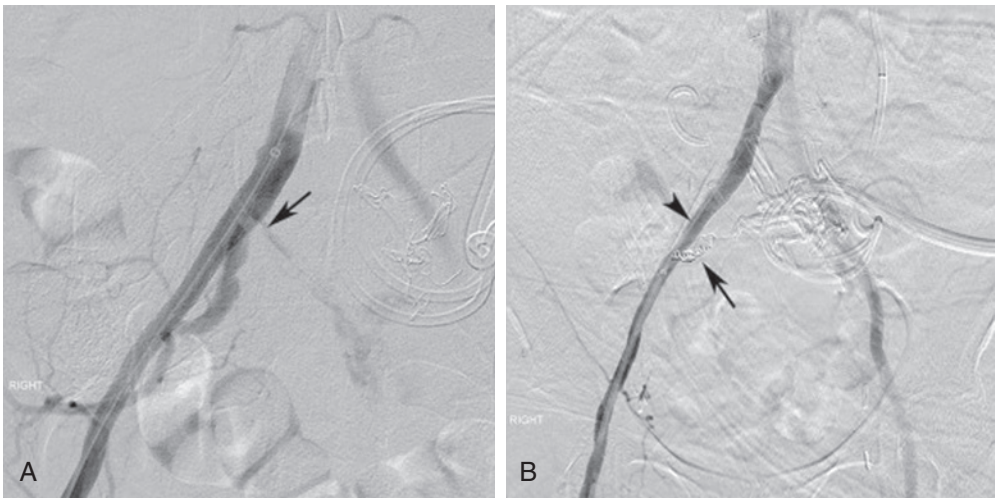


Figure 12.9 A, Right common iliac artery digital subtraction angiography demonstrating fistulous communication at the level of the bifurcation with the passing right ureter (arrow). B, Successful exclusion of the ureteroarterial fistula on post contrast angiography by right common iliac artery covered stent placement (arrowhead) and coil embolization of the internal iliac artery (arrow). (From Siorek M, et al. Ureteroarterial fistula following retrograde ureteral stenting in a patient with a double-barreled wet colostomy for cervical cancer. Gynecol Oncol Rep, 2015;13:44-6.)

As we have discussed, most ureteral fistulas, including all ureterovaginal fistulas, involve the distal third of the ureter. Given this, the standard practice is to excise the damaged ureter and perform a ureteral reimplant, with or without intramural tunneling. Relaxing maneuvers such as a psoas hitch or Boari flap can prove useful to ensure a tension-free anastomosis.[70,87,88] Several series have demonstrated equivalent outcomes with robotic-assisted UVF repair, with the additional benefit of improved intraoperative visualization.[42,64] Middle and upper ureteral fistulas, not involving the vasculature, can often be managed with a ureteroureterostomy given the short length of defect.[80] Whenever possible, tissue interposition is recommended to provide additional blood supply to the healing ureter, as well as isolate the repair from intraperitoneal structures or additional suture lines created as part of concomitant bowel or vaginal repairs.[61] An omental wrap is best suited for this purpose; however, care must be taken to form a broad pedicle to allow the wrap to maintain viability after mobilization. Urinary diversion can be considered when a patient presents with a recalcitrant or devastating injury.

Management of ureteroarterial fistulas is an active area of inquiry. Historically, open intervention was necessary,[66] but with advances in interventional radiology and endovascular stents, minimally invasive management is now preferred in the hemodynamically stable patient,[65,75,78] with success rates of 76% in a contemporary series (Fig. 12.9).[89]

Intestinal Fistula

ETIOLOGY

Abnormal communications from bowel to bladder may occur in many settings including intestinal disease and surgical misadventure. Inflammation secondary to diverticulosis is a common cause of intestinal fistulas, as are Crohn's disease, colorectal malignancy, pelvic trauma, and radiotherapy. Diverticular disease usually occurs in the sigmoid colon in about 90% of cases and, when complicated, accounts for about 60% of all colovesical fistulas.[90] Colon and bladder malignancies may also account for up to 20% of all cases. Crohn's disease is the third most common cause of intestinal fistulas and is the most common cause of ileovesical fistulas in younger patients. Crohn's disease should be considered in all patients with bowel stenosis and an associated intraabdominal abscess.[91] A ruptured diverticulum or pelvic phlegmon are risk factors for development of a fistula.

Radiation to the pelvis and prostate may be delivered via an external beam or by brachytherapy. The mechanism of injury is secondary to obliterative endarteritis eventually leading to ischemia of the mucosa and subsequent fistulization. The more common techniques for external beam therapy are three-dimensional conformal therapy and intensity modulated radiation therapy. Alternatively, one may elect to have proton beam therapy. Genitourinary complications seem to be similar with external beam or proton beam therapy so there may be no benefit to one over the other. Permanent interstitial brachytherapy is a definitive treatment for localized prostate cancer.

Radiation for prostate cancer brings unique complications including rectourethral fistulas (RUFs). There has been a shift in the cause of RUFs from iatrogenic injury to approximately 50% resulting from some derivative of radiotherapy for malignancy.[92] There has been a demonstrated correlation between radiation dose to the prostate and subsequent urethral stricture formation; it is believed RUF follows this correlation. Urethral stricture and bladder neck contracture leading to high-pressure voiding may also have a positive correlation. RUF has been associated with post-radiation transurethral resection of the prostate, post-radiation rectal biopsy, and post-radiation pelvic surgery. Salvage procedures for prostate cancer such as salvage

prostatectomy and cryotherapy also carry high rates of RUF. Salvage high-intensity focused ultrasound (HIFU) and brachytherapy have a 16% and 12% rate of developing RFU, respectively.[93]

PRESENTATION

The presenting symptoms associated with fistulas involving the intestines and bladder are those common to the lower urinary tract. Often patients will report frequency urgency and recurrent urinary tract infections. Intestinal fistula should be considered in the differential diagnosis of patients with urinary tract infections refractory to antibiotics. Fifty per cent of patients with a vesicoenteric fistula will present with pneumaturia and fecaluria. Patients with colovesical fistulas may complain of tenesmus. The symptom complex of tenesmus, suprapubic pain, frequency, and dysuria is known as Gouverneur's syndrome.[94] The presentation of radiation-induced intestinal fistula is similar as described previously in this chapter. They are associated with a delayed presentation and may declare themselves months to years after the initial therapy. While rare, patients may develop signs and symptoms of sepsis. Abdominal pain associated with abdominal abscess is common in fistulizing Crohn's disease. RUFs are usually small and located in the bladder neck or trigone. RUF secondary to radiation may be large and involve the posterior urethra. Fecaluria may be a presenting symptom.[92]

DIAGNOSIS

Cross-sectional imaging is the modality of choice for the diagnosis of intestinal fistulas. This may be enhanced with oral and intravenous contrast. Triphasic CT offers excellent anatomic detail of the genitourinary system. MRI is useful to delineate complex fistulas involving multiple bowel segments as well as the viability of the surrounding tissue. Ultrasound has a limited role in the diagnosis of enterovesical fistulas (Fig. 12.10).[94]

Patients with enterovesical fistulas should undergo a careful preoperative evaluation. Cystoscopy is a useful diagnostic tool; however, it may be nondiagnostic 60% of the time.[94] Patients with a RUF should undergo examination under anesthesia, retrograde urethrogram, voiding cystogram, biopsy of the fistula if indicated, and proctoscopy. This allows for evaluation of the fistula's size and location, but also determine if a concurrent bladder neck contracture or urethral stricture is present. Colonoscopy is not of high yield in patients with an intestinal fistula; however, it should be an integral part of the patient evaluation, particularly in patients with history of radiation or malignancy or if malignancy needs to be ruled out. Physical examination should assess for patency of the urethra and ensure there is no evidence of urinary obstruction present as high-pressure voiding may be an inciting factor. An RUF may be palpated and characterized on digital rectal examination.[93]

MANAGEMENT

The surgical management of intestinal fistula includes resection of the fistulizing segment of bowel with primary anastomosis of healthy tissue. Fecal diversion should be considered in cases of frank contamination of the abdomen and/or sepsis. One of the larger series on the treatment of RUF boasted robust results, which they feel in part is secondary to performing fecal diversion on all their patients prior to fistula repair. They reported 100% success repairing RUF in nonradiated patients and 84% in radiated patients with a single procedure (buccal onlay and gracilis muscle interposition flap) and 20 months of follow-up.[95] Resection of the fistulous tract from the bladder is at the discretion of the surgeon; however, closure of the cystotomy in a primary fashion is always recommended.

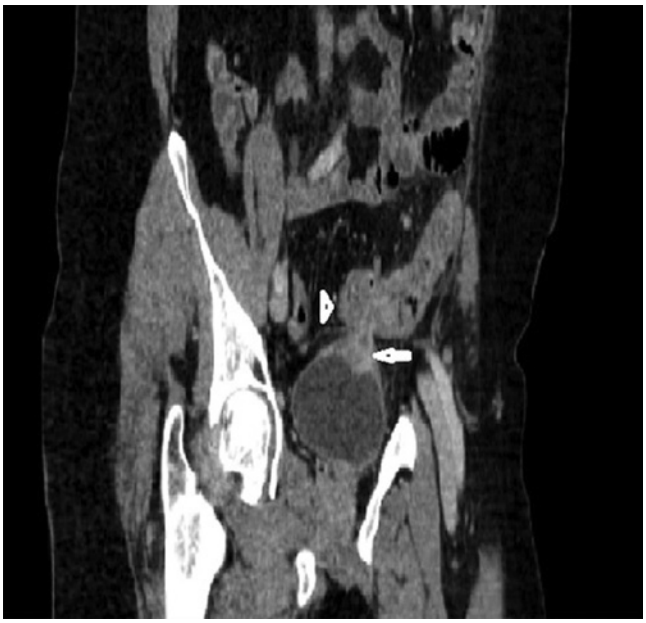


Figure 12.10 Sagittal image shows bladder wall thickening (arrow) adjacent to a loop of thickened sigmoid colon (arrow head). (From Golabek T, et al. Enterovesical fistulas: aetiology, imaging, and management. Gastroenterol Res Pract. 2013;2013:617967.)

RUF often requires a combination of onlay grafting and interposition muscle flap for closure. The anterior, perineal sphincter-sparing approach is the optimal approach for closure of all RUFs (simple or complex). RUF in the bladder neck/trigone region can be closed in a primary fashion.[95] Minimally invasive approaches have been described but are best reserved for experienced surgeons as the inflammatory reaction and subsequent adhesions often lead to a loss of surgical planes and difficult dissections.[90] Attempted repairs in patients with history of radiation are at a higher risk for failure, and some patients will require urinary diversion.[93] A transanosphincteric (York-Mason) approach allows for better exposure of the RUF with limited permanent damage to the anal sphincter. This approach also provides adequate space for the use of tissue interposition with gracilis muscle flaps, rectal advancement flaps, and multilayered closure.[93] These approaches are best left for referral centers that offer the services of experienced reconstructive genitourinary surgeons.

Colovaginal fistulas may be encountered particularly in the setting of diverticular disease. These patients have poor outcomes with primary repair and may require ileostomies in cases of primary anastomosis of the colon in order to prevent the high morbidity rates associated with

anastomotic leak. There are other rarer fistulas that are infrequently encountered in clinical practice, but which should be mentioned for the sake of completion, such as communications between the bladder and uterus as well as fistulas to the fallopian tubes.

Conclusions

The key to the successful management of any fistula is adherence to a few basic principles. Early intervention decreases patient discomfort and is as successful as delayed repairs in the nonradiated patient. A high index of suspicion must always be maintained to diagnose fistulas, as the presenting symptoms can be variable. The first repair is the best chance at a successful repair. Surgical principles include maintaining separate, nonoverlapping suture lines, a multilayered closure, a water-tight repair, and adequate postoperative urinary drainage. It is always important to maintain meticulous medical documentation as these cases may often have legal implications.

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Chapter 12 Questions

1. What is the most common cause of urethrovaginal fistula in the developing world?
   a. Obstructed labor
   b. Chronic catheterization
   c. Pelvic prolapse repair
   d. Malnutrition
   e. Urethral diverticulectomy

2. What is the risk of developing a urethrovaginal fistula following synthetic midurethral sling placement?
   a. 1 in 10,000
   b. 1 in 1000
   c. 1 in 500
   d. 1 in 100
   e. 1 in 50

3. What percentage of vesicovaginal fistulas (VVC) involves the ureter?
   a. 0.1%
   b. 1%
   c. 5%
   d. 10%
   e. 25%

4. Ureteral fistulas are most commonly the sequelae of:
   a. Urologic surgery
   b. Colorectal surgery
   c. Gynecologic surgery
   d. Vascular surgery
   e. Obstetric surgery

5. Undiagnosed ureteral injury during hysterectomy is most common during vascular control of the:
   a. Uterine artery
   b. Vaginal artery
   c. Internal iliac artery
   d. Ovarian artery
   e. Superior vesical artery

6. What is the optimal diagnostic approach when ureteroarterial fistula is suspected?
   a. CT of the abdomen and pelvic with delayed contrast images
   b. Ureteroscopy
   c. Intravenous pyelogram (IVP)
   d. Angiography
   e. Laparoscopic evaluation

7. Ureteral fistula repair is performed in a delayed fashion in order to:
   a. Allow the serum creatinine to plateau
   b. Ensure the full extent of the injury will be apparent
   c. Provide the patient with adequate recovery from initial surgery
   d. Minimize further trauma to GU tract
   e. Ensure adequate workup can be completed

8. A 54-year-old female with history of uterine malignancy complains of frequency and leakage of urine 6 months after completion of radiation therapy. CT urogram demonstrates no hydronephrosis and a vesicovaginal fistula. What is the best next step in management?
   a. Cystoscopy with biopsy
   b. Urodynamic testing
   c. Retrograde pyelogram
   d. Vaginoscopy
   e. VCUG

9. What is the incidence of vesicovaginal fistula formation with the placement of midurethral sling?
   a. 1/10
   b. 1/100
   c. 1/1000
   d. 1/5000
   e. 0

10. What is the main irrigation of a Martius flap?
    a. Anterior labial artery
    b. Obturator artery
    c. Internal pudendal artery
    d. Uterine artery
    e. Gluteal artery

Case Studies

CASE 1

A 72-year-old female patient is diagnosed with locally advanced cervical cancer status post radiation, complicated by right ureteral obstruction. The patient is managed with periodic right ureteral stent exchanges. One week after an uncomplicated stent exchange, the patient presents to the emergency department after her aide witnessed gross hematuria. In the ER, her vital signs are stable. Her abdominal and gynecologic exam show no blood in the vaginal vault. She is found to have an unchanged hematocrit and creatinine. Her urinalysis reveals yellow urine with 30–50 RBC and 30–50 WBC with few bacteria.

1. What is a risk factor for ureteroarterial fistula (UAF) formation in this patient?
   a. Age
   b. Indwelling ureteral stent
   c. Hematuria
   d. Pyuria
   e. Obesity

2. What is the best option for management of this patient?
   a. Antibiotics
   b. Angiography
   c. Open repair
   d. Ureteral stent exchange
   e. Watchful waiting

3. What is the optimal timing for surgical repair?
   a. Immediate surgical repair
   b. Surgical repair in 6 weeks
   c. Remove the stents now and repair in 3–6 weeks
   d. Repair in 6 months
   e. Do not repair

CASE 2

A 36-year-old G3P2 female patient presents for evaluation of frequency, urgency, nocturia, and leakage of urine onset 2 days after cesarean section. She reports leakage with activity as well as with urgency. She feels she is always leaking urine. She denies nausea, vomiting, fever, chill, or flank pain. Cystoscopy is normal.

1. What is the best test to exclude damage to the upper tracts?
   a. CT urogram
   b Double dye test
   c. Renal ultrasound
   d. Urodynamic testing
   e. VCUG

2. What is the best test to diagnose concomitant voiding dysfunction?
   a. CT urogram
   b. Double dye test
   c. Cystoscopy
   d. Urodynamic testing
   e. Renal sonogram

3. When should this be surgically corrected?
   a. Immediate repair
   b. 2 weeks
   c. 3 months
   d. 6 months
   e. 3 years

Answers

1. **c.** Studies suggest that in countries with limited access to health care, physicians not aptly trained in performing emergent cesarean section are often unable to execute these procedures leading to prolonged labor and the complications associated with the prolonged labor complex including subsequent fistula formation. In these countries death is often associated with obstetric complications.[1]
2. **d.** The risk of developing a fistula during a sling procedure for stress urinary incontinence is cited at 1%.[48]
3. **d.** Once a fistula is suspected, attention must be turned to promptly identifying its size and location, as this will dictate management. Imaging of the upper tract is mandated as 10% of VVFs may have concomitant injury to the ureters.[21]
4. **c.** They have been reported in 2–3% of laparoscopic hysterectomies[8,57] and in 4.5% of 6000 obstetric or gynecologic surgeries in a multinational study conducted in the developing world.[58]
5. **a.** Ureterovaginal fistulas are the most common ureteral fistulas. They typically form following an undiagnosed ureteral injury during hysterectomy if the ureter is inadvertently clamped or ligated in an attempt to control bleeding from the uterine artery.
6. **d.** Angiography is the present standard of care for diagnosis of ureteral fistula.[66]
7. **b.** Repair is often delayed for at least 6 weeks to allow full delineation of the diseased ureter.[72]
8. **a.** In fistula arising after surgery for malignancy or radiation, one must also exclude the possibility of a recurrence within the fistulous tract with a biopsy, prior to surgery.
9. **c.** The incidence of vesicovaginal fistula formation from synthetic sling material used to correct stress urinary incontinence is low and reported across the medical literature as occurring in 0.1% of cases.[16]
10. **c.** The pedicle originates from the posterior labial artery, a branch of the internal pudendal artery.

CASE 1

1. **b.** Chronic ureteral stents are a significant risk factor for UAF with 74% of patients known to have a history of stenting. Gender, radiation, pelvic cancers (bladder, cervical, and colorectal), and vascular disease are also risk factors for UAF.[66,67]
2. **b.** Angiography is the present standard of care for diagnosis of ureteral fistula.[66] It is also a potentially therapeutic test; if the ureter is opacified, the fistulous connection can be embolized. The sensitivity of angiography has been estimated to be between 50% and 69%.[78,79]
3. **c.** Repair is often delayed for at least 6 weeks to allow full delineation of the diseased ureter.[72] In a radiated patient, additional time to repair is prudent given the slow appearance of injury, usually about 6 months. Indwelling nephroureteral stent or an internal ureteral stent can result in periureteral inflammation, and some would advocate removal for several weeks prior to repair.

CASE 2

1. **a.** Imaging of the upper tract is mandated as 10% of VVF may have concomitant injury to the ureters.[21] Historically this had been achieved with intravenous pyelograms. This has in great part been replaced by retrograde pyelograms and contrast-enhanced cross-sectional imaging with a urographic phase, given its superior anatomic detail.
2. **d.** Urodynamic studies may be of diagnostic value in the evaluation of a fistula, particularly if there is suspected concomitant storage or voiding dysfunction. Videourodynamic testing has the added benefit of providing anatomic as well and functional information. Patients with injuries in the trigone or bladder neck are at risk for developing detrusor overactivity and stress urinary incontinence.[25]
3. **a.** Studies have shown that if a fistula is identified in the acute setting it may be treated successfully.[32] Zimmern et al. observed that surgical repair performed within 2 to 3 weeks of the injury had no increased morbidity or failure rates when compared with delayed repair.

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13 Management of Urine Leak

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CHAPTER OUTLINE

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Incidence and Differential of Urinary Leak
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Pyeloplasty
Conclusions
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KEY POINTS

1. Many cases of post operative urinary leak are asymptomatic and seen on imaging only. When symptoms of Urinary Leakage occur – they are extremely variable and can include ascites, electrolyte abnormalities, ileus, or sepsis. A high index of suspicion by the surgeon is always required even in the absence of elevated drain outputs.
2. Risk factors for urinary leak after partial nephrectomy include intra-renal pelvis, complex nephrometry score, prolonged ischemic times and complex collecting system entries and repairs.
3. Risk factors for urinary leak after radical prostatectomy include prior TURP, anatomic considerations leading to difficult intraoperative anastomosis (obesity, narrow pelvis, pelvic lipomatosis, short urethral length etc), increased EBL, pelvic hematoma, postoperative UTI, early learning curve, and salvage prostatectomy after radiation therapy.
4. Risk factors for urinary leak after cystectomy include palliative exenteration, obesity, prior pelvic radiation, extensive mobilization of the ureters (particularly left) and short enteroureteric anastomoses under tension.
5. Management strategies involve maximal drainage of the leak (via a stents and/or drains) which is often followed by delayed but spontaneous closure. Occasionally close observation under select circumstances may be acceptable.
6. Patience is essential and individuals should be counseled that their stent and drain may occasionally need to stay in place for weeks or rarely months. Operative intervention should be infrequent and only if infection or other systemic manifestations mandate.
7. Surgical intervention, other then endoscopic, is rarely necessary. Reoperations should be avoided in most stable patients until all endoscopic options are exhausted and a prolonged period of maximal drainage is attempted.

Introduction

Urinary leak is one of the more common complications that urologists encounter. Urinary leak occurs with both major and minor urologic interventions including radical cystectomy with urinary diversion, radical prostatectomy, partial nephrectomy, ureteral reimplant, transurethral resection of the bladder as well as urologic trauma and stone disease. The incidence of urinary leak associated with these events is unknown and likely underreported.

Two broad categories of urinary leak exist: intraperitoneal and extraperitoneal. Presenting symptoms may be different

depending on the location. Extraperitoneal leaks may present earlier with pelvic pain or a pelvic pressure-like sensation as the urine becomes contained in a fixed space (retroperitoneal) and compresses adjacent organs. Additionally, leakage from the surgical incision site (usually lower midline or port site) can occur as fluid flows down the path of least resistance. The urine may become infected secondary to recent surgical interventions, thereby promoting wound infection or abscess formation. It can incite an ascending urinary tract infection involving the entire retro peritoneum and investing fascial layers. The management of extraperitoneal urine leaks is generally more conservative and consists primarily of supportive care and tube drainage.[1]

Intraperitoneal urine leaks are usually not contained. If there is no associated urinary tract infection, the presence of sterile urine in the peritoneal space can be tolerated for several days and can present in a delayed fashion with increasing abdominal distention, ascites, or progressive azotemia.[2,3] Patients often develop electrolyte imbalances including hyponatremia, hyperkalemia, and metabolic acidosis whereas the peritoneum functions as a dialysis membrane.[4–6] Spontaneous or traumatic intraperitoneal urinary leaks can represent a diagnostic dilemma. Indeed, some patients have been placed on hemodialysis by unsuspecting clinicians to reverse azotemia only to realize later the presence of urine in the paracentesis fluid.[6,7] Uroperitoneum can also result in a paralytic ileus,[3] fascial dehiscence as a result of increased abdominal pressure,[8,9] and a predisposition to intraabdominal and wound infections. In the setting of urinary tract infection, immediate peritonitis can ensue, leading to sepsis, which may require pressors and ICU support and potentially can lead to death.

This chapter will focus on the incidence, management, and prevention of urinary leak specifically as it relates to individual urologic procedures including partial nephrectomy, radical prostatectomy, and urinary diversions.

Urinary Leak Associated With Partial Nephrectomy

DEFINITION AND DIAGNOSIS OF URINARY LEAK

The definition of what constitutes a urinary leak following partial nephrectomy varies in published literature. Two main definitions exist. The first is clinical and requires a persistent drain output varying from 2 to 7 days whose chemical analysis is consistent with urine, defined as an elevated drainage creatinine level greater than that of the simultaneous serum level.[10,11] While there is no specific cutoff for how much higher the drainage creatinine must be when compared to serum, any elevation should arouse suspicion in postoperative patients; however, a level of twofold or more is most suggestive.[11] Care must be taken when interpreting these results in patients with severe impairment of GFR and CKD 4 and 5. The second definition of a urine leak following a partial nephrectomy is radiographic and based on the appearance of perioperative fluid collection on postoperative imaging.[12,13] In this case, the differential diagnosis includes a serous, lymph, or urine collection, and the diagnosis must be confirmed by aspiration and creatinine analysis.

In cases of elevated or persistent drain output, a drain fluid creatinine level can be checked based on clinical suspicion (complex partial nephrectomy, prolonged ischemic time, etc.) or radiographic findings of contrast extravasation on CT, MR, or retrograde pyelogram. The timing of a urinary leak is typically within the first 14 days post partial nephrectomy. Care should be taken to avoid a false sense of security with low drain outputs after resection of complex tumors with prolonged ischemia whereas acute tubular necrosis may prevent the kidney from making urine within the first several days. Therefore as the kidney recovers and urine production increases, the drainage may pick up as the leak evolves. If a serum creatinine enables the use of iodinated contrast, a CT urogram is the single best test to perform with particular attention to the excretory phase to evaluate the renorraphy, collecting system, and the entire ureter for sites of urinary leak.

SYMPTOMS OF URINARY LEAK

In the majority of series in the published literature, most patients with a urinary leak are asymptomatic and present with increased drain output that is then confirmed to be consistent with urine.[11,14–19] In a study by Potretzke et al. evaluating urinary leak following robotic partial nephrectomy, the authors only tabulated symptomatic undrained urinary leaks, whereas all drains were removed prior to discharge. Patients presented at a median postoperative day (POD) 13 with symptomatic urinary leak with fever (14%), gastrointestinal complaints including ileus (29%), and pain (36%).[12]

INCIDENCE AND DIFFERENTIAL OF URINARY LEAK

The incidence of urine leak from renorraphy sites ranges from 1.5% to 18.5% after open partial nephrectomy (OPN),[10,11,14,18,20–28] 1.5–16.5% after laparoscopic partial nephrectomy (LPN),[14–17,19,25–27,29] and 0.78–3.7% after robotic partial nephrectomy (RAPN).[12,13,18,19,27,28,30] The incidences vary with respect to the definition of urinary leak used (clinical, biochemical, and/or radiographic). Additionally, the literature is replete with inaccurate information regarding the timing of postoperative urinary leaks vis-à-vis drain removal. In one RAPN series (n = 1791) where all patients' Jackson-Pratt (JP) drains were removed prior to hospital discharge, the authors report an absolute-symptomatic leak rate of 0.78%.[12] In a combined OPN/LPN series consisting of 1118 cases, an overall leak rate of 4.4% was noted with delayed leak after drains were removed occurring in 0.4%.[16] It is certainly likely that not all urine leaks following partial nephrectomy are clinically symptomatic, and the true incidence is therefore unquantifiable. According to the American Urological Association (AUA) guidelines on the management of the stage 1 renal masses, the incidence of a urinary leak following partial nephrectomy is 4.1–4.4%[31] while that of symptomatic leaks requiring drainage is closer to 0.78%.

When a urinary leak is diagnosed following partial nephrectomy, a clinical incidence of suspicion must remain for the possibility of a ureteral injury or necrosis as its cause. Ureteral injuries are reported to occur in 0.3% after LPN and

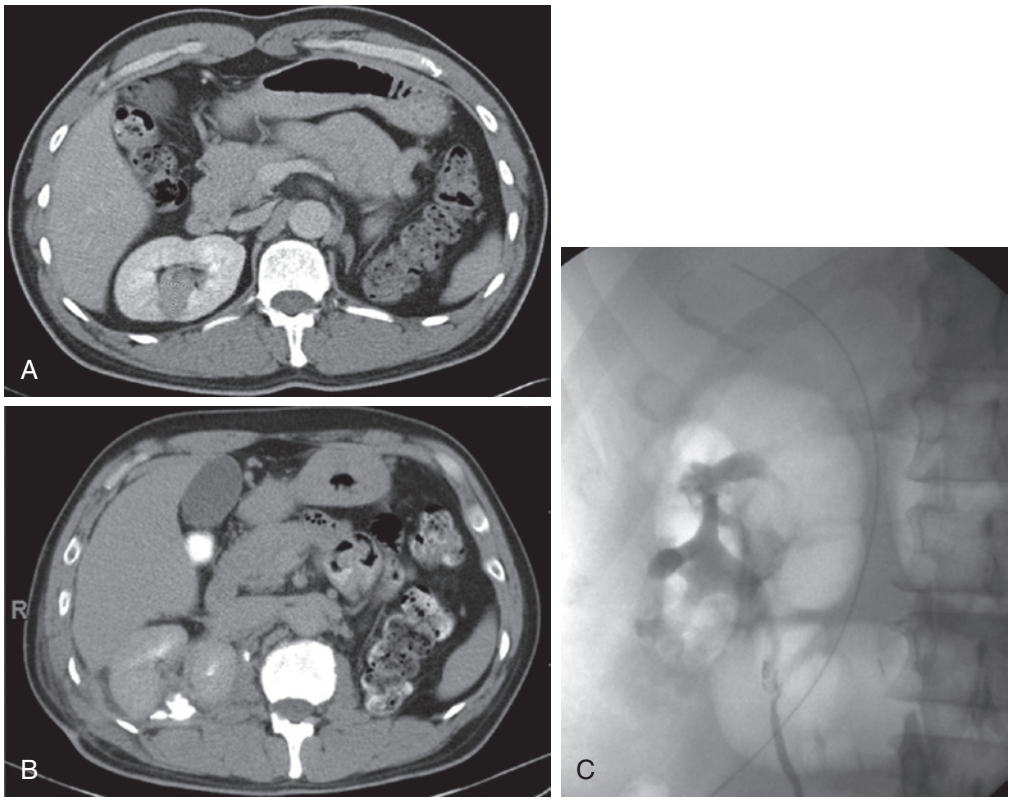


Figure 13.1 Urinary leak after partial nephrectomy in a solitary kidney of a patient with a highly complex tumor (nephrometry score 2+3+3+P+3 = 11P) with proximal ureteral stricture. Ureteral stent was placed on postoperative day 4, leading to resolution of urinary leak in 35 days.

0.6% after RAPN.[25] Idiopathic ureteral injuries are usually identified intraoperatively and do not result in a urinary leak if repaired and properly drained. However, unidentified ureteral injuries can occur and need to be considered if a persistent urinary leak is encountered. Additionally, ureteral obstruction must always be considered and excluded, particularly for high-output urinary leaks following PN. While new-onset ureteropelvic junction obstruction (UPJO) is described in 1% of patients following PN,[26,29] most cases of ureteral injury or obstruction occur as a result of iatrogenic crush, thermal or transection injury, and/or ischemia due to over-dissection. Downstream obstruction from the site of leakage can increase the persistence and amount of a urinary leak from the renorrhaphy site (Fig. 13.1).[14]

RISK FACTORS OF URINARY LEAK

Most studies evaluating risk factors of urinary leak compare those with and without a leak without adjusting for other clinicopathologic characteristics of a patient. These studies indicate that central/endophytic tumor location,[11,12,14] large tumor size,[11,12,14,16] collecting system entry,[11,12,14,15,18,19,22] RENAL nephrometry complexity,[22,27] downstream obstruction (UPJO, ureteral stricture, infundibular stricture, BPH with high-pressure voiding),[14] intrarenal pelvis >50%,[18,22] increased estimated blood loss,[16–19] preoperative CKD stage ≥III status,[19] increased warm ischemia time,[12,16,18] increased operative time,[12] surgeon's learning curve,[19] and surgical approach (increased with OPN vs RPN)[18] are all risks and more highly associated with urinary leak. Other studies indicate that surgical approach,[16,28] tumor multifocality,[11,16] operative time,[22] or EBL[22] are not predictive of urinary leaks.

Two studies evaluated the risk factors for urinary leak following PN using multivariable models. One study suggested that a surgeon's early operative experience (odds ratio [OR] 7.8), tumor proximity to collecting system (OR 9.2), and preoperative CKD stage ≥ III (OR 3.1) are indicative of urinary leak after adjusting for other factors including surgical technique, operative time, warm ischemia time, race, BMI, individual RENAL score attributes, and use of intraoperative ureteral catheterization.[19] Tomaszewski and Uzzo et al. demonstrated that an intrarenal pelvis (OR 24.8), endophytic tumor (OR 4.5), and collecting system entry (6.1) are most predictive after adjusting for age, gender, race, BMI, Charlson comorbidity index, surgical approach, ECOG score, individual RENAL attributes, ischemia time, and operative time.[18] To measure intrarenal pelvis anatomy these authors developed the renal pelvic score (RPS) as measured on CT or MRI by drawing a line connecting the two polar lines (upper and lower) and quantifying the proportion of renal pelvis volume within the kidney parenchyma. An RPS >50% is considered intrarenal and at a higher risk of urinary leak with prolonged time to closure in cases of complex PN.

PREVENTION OF URINARY LEAK

The knowledge of risk factors for urinary leak is paramount in efforts to avoid this complication. Techniques

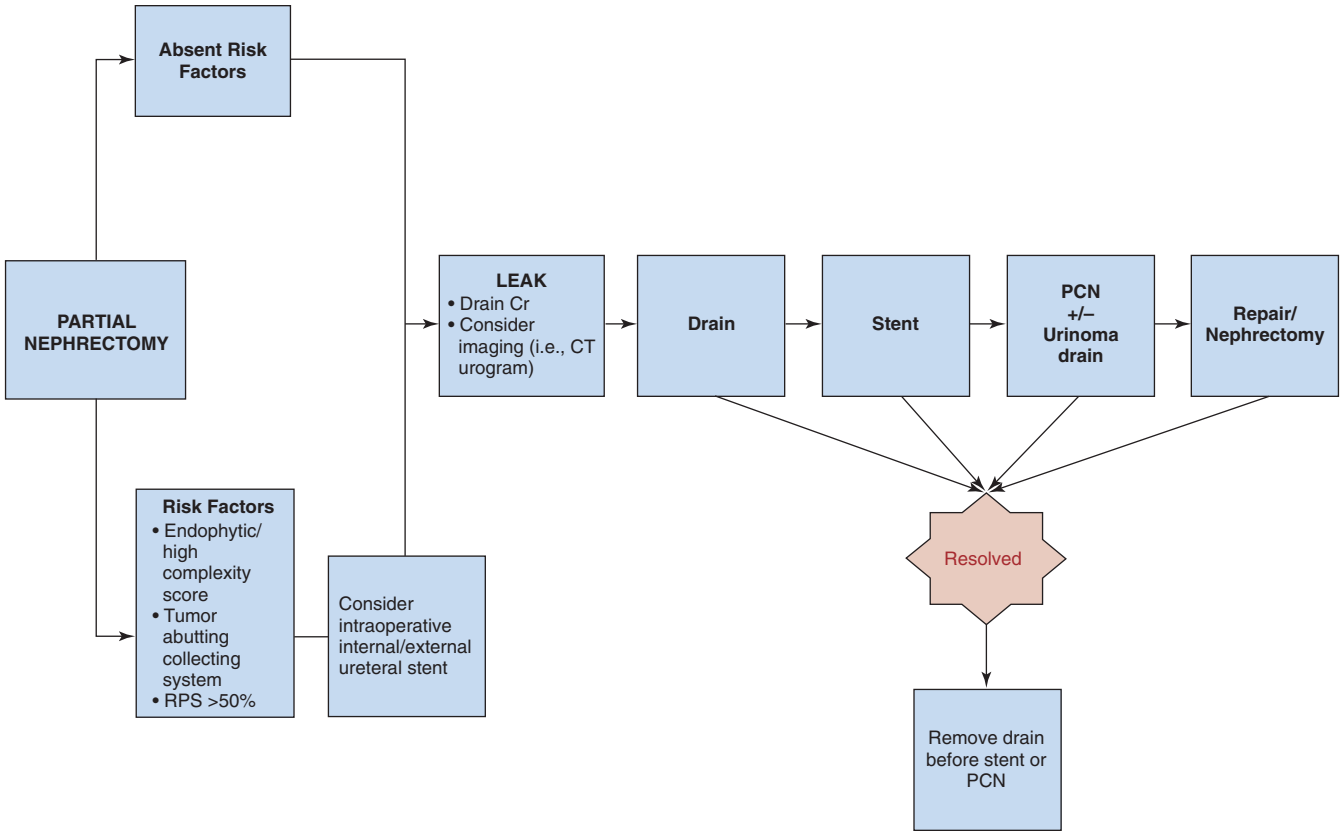


Figure 13.2 Treatment algorithm of urinary leak after partial nephrectomy.

used include the placement of a preoperative ureteral catheter for localization, injection of methylene blue to identify collecting system entries, and "priming" with intravenous indigo carmine prior to arterial clamping. Early series of partial nephrectomy routinely place ureteral catheters and inject saline or methylene blue to help identify intraoperative urinary leakage during excision and reconstruction.[11,14,15,25] However, recent studies question the utility of this since no difference in postoperative urinary leak was seen in those with and without the ureteral stent despite a higher incidence of collecting system entry detection intraoperatively.[10,19,32]

In our practice, we are highly selective regarding in whom we place preoperative ureteral stents based primarily on complex nephrometry score, prior surgery, and intra-abdominal or retroperitoneal anatomy. In these cases we place a 5Fr ureteral stent using a flexible cystoscopy prior to patient positioning and leave it for 24–48 hours as a preventive measure to decrease renal pelvis pressure in select patients with intrarenal pelvis, endophytic tumors, or tumors abutting the collecting system. Occasionally we will use it to instill retrograde saline with 1 mL of methylene blue to identify the collecting system entry. As these are the patients with highest odds of developing a urinary leak, we feel that this may contribute to identifying and preventing a urinary leak. This is, however, difficult to test in a prospective study. Additionally robotic or loupe magnification during excision and renorrhaphy is considered very helpful. The complexity of a collecting system entry should be assessed prior to and during excision, with care taken to avoid complete infundibular transection or extensive unroofing, which would make reconstruction complicated. Moreover, suture occlusion during fastidious repair should be carefully avoided.[33]

TREATMENT OF URINARY LEAK (SEE FIG. 13.2)

More than 80% of urinary leaks following PN are diagnosed in otherwise asymptomatic patients with prolonged output per JP drain, while the remainder is diagnosed after drains have been removed.[14,16] Given that the majority of patients presents asymptomatically, we routinely place JP drains in those who have significant risk factors for urinary leak (large endophytic lesion, collecting system entry, or intrarenal pelvis). Avoidance of JP drains in many of these patients without risk factors has been shown to be safe without an increase in operative interventions for urinary leak drainage.[20,30]

Fortunately, the majority of patients who develop a urinary leak can be managed with a combination of prolonged JP drain and selective use of Foley catheterization without any other operative intervention.[10,11,13,14,16,18,19,22–24] If, however, prolonged JP drain does not decrease the outputs, a ureteral stent should be considered. Ureteral stents have been employed in 20–60% of cases[10–12,14–16,18,19,22,23] of prolonged urinary leak with successful resolution of the leak in the vast majority of cases.[14] The stents are usually placed at a median time of 2–3 weeks[12,14] after partial nephrectomy but could be placed sooner in the case of excessively high drain outputs. A gentle retrograde pyelogram should be

done at the time of stent placement to assess patency of the ureter and good positioning of the stent. A leak does not need to be demonstrated on retrograde if there is clinical evidence of a leak. The JP drains are kept until output significantly declines. The stents may be kept in place for 6–12 weeks,[14,15] and a retrograde pyelogram may be done to evaluate for leak before they are removed; however, our practice is to omit retrograde unless clinically indicated. The combination of a ureteral stent with intraabdominal JP drain may result in over 90% resolution of urinary leak.[14,16,18] The median duration of a urinary leak is between 20 and 64 days.[14,16,22,24] It is expected that unobstructed patients will heal within a reasonable time period of 1 to 4 weeks.[14] Some experts advocate that the drain be placed to straight drainage as opposed to bulb suction as this may prolong urinary leakage.[34]

The use of Foley catheters has been advocated in cases of prolonged or high-output drainage, but we reserve this primarily for men with high-pressure voiding. Alpha-blockers are often used to minimize bladder pressures, which may induce reflux up the stent. Care should be taken to maintain good hygiene of the drain site. Drainage may reduce gradually or occasionally quite precipitously. If this occurs, an ultrasound is often helpful to assess for retroperitoneal fluid reaccumulation or hydronephrosis. Drains are usually removed before the stent, which should be maintained for several additional weeks after the leak has clinically resolved. In cases of persistent high-output leakage despite maximal drainage, ureteral or stent obstruction, unrecognized additional injuries, or necrosis should be considered. Although not scientifically evaluated, desmopressin administration has been suggested to reduce the duration of urinary leak.[35,36]

Whereas the majority of urinary leaks resolve on their own following PN, patience is essential, and individuals should be counseled that their stent and drain may occasionally need to stay in place for weeks or, rarely, months. In these cases some have successfully accelerated resolution with dual ureteral stents or a fashioned 14Fr to 16Fr ureteral catheter.[37,38] An additional urinoma drain or a nephrostomy tube may rarely be necessary and has been utilized along with stents on occasion.[12,16,18,19,22–24]

The astute clinician should be very hesitant to ever reoperate on a urinary leak following PN as long as obstruction is ruled out and drainage is maximized. Very rare instances of persistent leakage may require attempted renal or ureteral reconstructive or completion nephrectomy.[11,22,23,25] However, prior to undergoing nephrectomy, a careful pyelogram is needed to assess and to rule out ureteral strictures, infundibular stenosis, or ureteropelvic junction obstruction, all of which may prolong the urinary leak.[14] If infundibular stenosis or strictures are identified, endoscopic dilations may be attempted and have been shown to be successful in case reports.[39,40] Additionally, there have been case reports of fibrin sealants that can be successfully injected in the offending calyx either percutaneously or by retrograde ureteroscopy to resolve any further urinary leakage.[41–43] However, any salvage endoscopic measures may require multiple operative procedures, and patients need to be counseled appropriately. Reconstruction may be preferable to nephrectomy depending on clinical circumstances.

Urinary Leak Associated With Radical Prostatectomy

DEFINITION AND DIAGNOSIS OF URINARY LEAK

There is no consensus on a definition regarding urinary leak following radical prostatectomy.[44] Similar to urinary leak after partial nephrectomy, two main definitions exist, one based on the persistence of prolonged drain output[45–48] with chemical analysis consistent with urine and the second based on radiographic findings on cystogram.[49–53]

In the majority of historical prostatectomy series, cystogram was routinely performed before catheter removal. It is diagnostic for a urinary leak with the identification of contrast extravasation. Several groups have attempted to classify and quantify cystogram findings. Fenig et al. classified these into no extravasation, mild leak (wisp of extravasation), moderate leak (extravasation 25% or less of instilled contrast medium), and major leak (>25% extravasation).[54] The purpose of the classification was to determine the need for a repeat cystogram. Patients with mild leak were recommended to undergo removal of Foley catheter without a repeat study. Patil et al. classified these into grade I (extraperitoneal within 6 cm of the urethrovesical anastomosis), grade II (extraperitoneal extending to the sidewall) >6 cm, and grade III (intraperitoneal).[49] Here, the purpose was to report on clinically significant versus nonsignificant leakage where patients with higher grades tended to require intervention. Both of these classification schemes illustrate the importance of a uniform definition of a urinary leakage.

Several other modalities including CT cystogram have been described to evaluate the urethrovesical anastomosis following radical prostatectomy. Although TRUS has been described, we do not recommend its use in the perioperative setting due to patient discomfort and less precise image resolution compared to CT.[55,56] CT cystogram has been shown to be more sensitive and accurate than cystogram.[57] Indications for CT cystogram as opposed to standard cystogram remain unclear. We recommend consideration of CT cystogram if the patient has suffered a prolonged or complicated course of urinary leakage with secondary complications such as bleeding, uroperitoneum, sepsis, or abscess. More extensive imaging may identify drainable collections or additional concurrent pathology. In these cases it is more critical that a leak is not present when catheter is removed.

Recently, many have questioned the overutilization of cystogram and attempted to stratify patients in whom it may be omitted. A study on open prostatectomy suggested that cystogram could be omitted in the absence of red or pink urine on POD 8 with a negative predictive value of 98.6%.[58] Another study suggested that an intraoperative test for a watertight anastomosis is predictive of no leakage. Ischia et al. recommended that over 97% of patients might avoid cystogram on POD 7 if a negative intraoperative leak test was confirmed.[59] With the advent of robotics and improved visualization and degrees of freedom during suturing, many have questioned the need in robotic procedures and perform a cystogram only in patients with a high clinical suspicion or risk of a leak such as in salvage prostatectomies following radiotherapy.[45,60] Guru et al. prospectively analyzed the

use of cystogram after robotic prostatectomy and illustrated that it can be safely avoided.[61]

SYMPTOMS OF URINARY LEAK

In the majority of published series, patients with urine leaks following prostatectomies are asymptomatic and present with increased drain output that is then confirmed to be consistent with urine or on a routine postoperative cystography. In Guillonneau et al.'s study, while 8.1% were diagnosed as having immediate postoperative urinary leak (persistent drain output for more than 6 days), 1.9% presented with secondary anastomotic leakage days after catheter removal.[48] These patients were diagnosed with acute pain, acute urinary retention, and peritoneal irritation symptoms. The study also illustrated that acute retention develops as a function of duration of catheterization where the incidence may be 5–25% at POD 2–3 and around 1% by POD 6. This may be due to resolution of anastomotic swelling. Removal of the catheter earlier in the postoperative course is, indeed, a risk factor for urinary retention.[54] While not all patients with retention develop a secondary urinary leak, retention appears to be a risk factor for anastomotic breakdown and leakage, particularly if the catheter is replaced traumatically.

An important subacute manifestation of urinary leak from the urethrovesical anastomosis includes osteomyelitis of pubic bone in the setting of a urinary tract infection. These patients can present with recurrent urinary tract infections, significant pubic and pelvic pain, and disturbance in gait.[62,63] Often these patients are not diagnosed in time and treated with repeat courses of antibiotics, which fails to improve their symptoms. These can present as early as 1 month postoperatively or can present over the next several months to several years.[62] Pelvic MRI remains the most sensitive and specific test to diagnose osteomyelitis of the pelvis.[64] When osteomyelitis has progressed, pelvic CT may reveal extravasation of intravesicle contrast from the fistulous tract into the bone causing fractures of pubic rami.[63]

While urinary leak may delay the return of continence following prostatectomy, it does not seem to worsen long-term continence rates at 1 year.[49,54] Several studies have suggested that urinary leak may predispose to the development of bladder-neck contractures (BNC),[45,49,60,65] while other studies indicate no significant relationship.[46,52,54] Postoperative urinary leakage when the anastomotic apposition is good seems unlikely to lead to BNC. However, prolonged and more extensive urinary leakage, resulting from an anastomotic gap, may cause scarring due to healing by secondary intention.[49,66]

INCIDENCE AND DIFFERENTIAL OF URINARY LEAK

The incidence of urine leak from urethrovesical anastomoses ranges from 0.5% to 29% after open radical prostatectomy (ORP),[51–54,60,67] 0.9%–22.3% after laparoscopic radical prostatectomy (LRP),[47,48,67–70] and 1.1%–12.7% after robotic-assisted laparoscopic prostatectomy (RALP).[46,49,50] The incidence varies with respect to the definition used with the radiographic definition, yielding higher incidences with a diagnosis of subclinical leak.[47,49,60] The incidence of leak is also time-dependent. In one ORP series, the leak rate at POD 8 was as high as 78% and decreased to 38% and 20% on POD number 11 and 14, respectively.[71] Similar data are available for LRP and RALP. However, due to improved continuous suturing with RALP, it is thought that RALP yields lower leak rates overall given improved tissue coaptation.

While there are several series with a high incidence of urinary leak overall, clinically significant anastomotic leaks are infrequent. Clinically significant anastomotic leaks can be defined as those that extended intraperitoneally, those that necessitated additional drainage, those that necessitated readmission due to ileus or dehydration, and those associated with fever and sepsis.[72] The incidence of clinically significant anastomotic leaks ranges from 0.36% to 2.3% in multiple series.[49,60,72]

Other sources of urinary leak following prostatectomy include bladder or ureteral injury not identified intraoperatively. The incidence of ureteral injury has been described to be 0.1% to 1.4%[68,70,73] and that of bladder injury 0.2% to 1.6%.[48,69,70] If bladder or ureteral injuries are suspected, a CT urogram or a cystogram is recommended.

RISK FACTORS OF URINARY LEAK

Risk factors for urethrovesical anastomotic leakage include previous TURP,[52,74] difficult intraoperative anastomosis,[51] increased EBL,[52,54,68] pelvic hematoma,[52,54,68] positive intraoperative flush test,[51] postoperative UTI,[51] ischemic heart disease,[52] obesity (due to difficulty accessing the urethra during anastomosis),[75] early learning curve,[47,67,68] and salvage prostatectomy after radiation therapy.[76] Additionally bladder neck reconstruction during RALP has also been shown to increase urinary leakage rates.[46] Neither suture type, number of sutures, nor interrupted versus running anastomotic sutures has been shown to be associated with leakage.[68,77,78] Barbed V-lock suture, rather than monofilament, has been shown to reduce the incidence of positive intraoperative leakage test, and the need for additional tightening of sutures.[79] However, it has not been directly related to postoperative urinary leakage. There has been no difference in leakage rate with open versus minimally invasive approach[60] or by extraperitoneal versus intraperitoneal surgical approach.[68]

PREVENTION OF URINARY LEAK

Several preventative measures to minimize urinary leak during prostatectomy have been described in the literature. The use of a side-fenestrated catheter over a conventional Foley catheter has been advocated in one study. In side-fenestrated catheters, the fenestration is located in the catheter below the balloon at the site of the anastomosis. The aim is to improve drainage emanating from the healing anastomosis. In a prospective randomized study of 250 patients undergoing RALP, patients randomized to a fenestrated catheter had a significantly decreased incidence of urinary leak (4.6% vs 12.3%).[80] Another preventive measure described is using fibrin sealant over the anastomosis to prevent leakage across the anastomosis. The maneuver may decrease overall intraabdominal drain output; however, the evidence is not strong for reducing the incidence of urinary leak.[81]

Another technical modality to prevent a leak is to relieve tension exerted on the urethrovesical anastomosis. Patel

et al. investigated the use of the posterior reconstruction of rhabdosphincter with the secondary outcome being leak rate.[50] The free edge of the Denonvillier's fascia is sutured to the posterior rhabdosphincter underneath the urethral plate. The intent is to minimize the downward mobilization of the urethra and reduce tension across the anastomosis. With this approach, the incidence of urinary leak was shown to reduce significantly (0.4% vs 2.1% in those without). Tewari et al. evaluated three different techniques of anastomosis – conventional anastomosis, anterior reconstruction, total anatomic restoration (anterior plus posterior reconstruction).[72] The aim of the latter two techniques was to relieve the tension on the anastomosis. Clinically significant urinary leak rates were lowest with total anatomic restoration (0.3%) followed by anterior reconstruction (1%) and highest with conventional anastomosis (2.3%). Ultimately, the best prevention of urinary leak following radical prostatectomy is the achievement of a tension-free, watertight urethral anastomosis.

TREATMENT OF URINARY LEAK (SEE FIG. 13.3)

Depending on the risk factors for urinary leak, an intraabdominal drain is considered at the time of prostatectomy. There are two divergent maxims associated with the pelvic drain: "when in doubt, drain" and "drains have only one role, they suck." In between these two extremes exists the informed approach. The goal of the drain is to avoid the sequela of uroperitoneum with its associated risks of ileus and electrolyte abnormalities and to minimize the need for an interventional procedure in the postoperative period.

Many utilize the intraoperative leak test as the main indicator as to whether or not to place a drain. Other factors taken under consideration include the technical difficulty with anastomosis (such as suture breakage, increased robotic arm collisions due to suture angles, tearing of urethra), prior TURP, or radiotherapy. In a prospective study on 846 patients undergoing prostatectomy, patients did not undergo drain placement if they had a negative leak test, adequate hemostasis, and no surrounding organ injury. This study illustrated no differences between those with and without drain placement with respect to leak rates.[82]

When leakage is confirmed in the postoperative period either by drain output or on radiographic imaging, the Foley catheter should be examined to ensure that it is draining and that it is not kinked or clogged. A gentle flush may be needed to clear away the debris. If high-output leakage is seen, the drain can be taken off suction and allowed to drain passively. The drain may be withdrawn a few centimeters as well to avoid suctioning against the anastomosis.

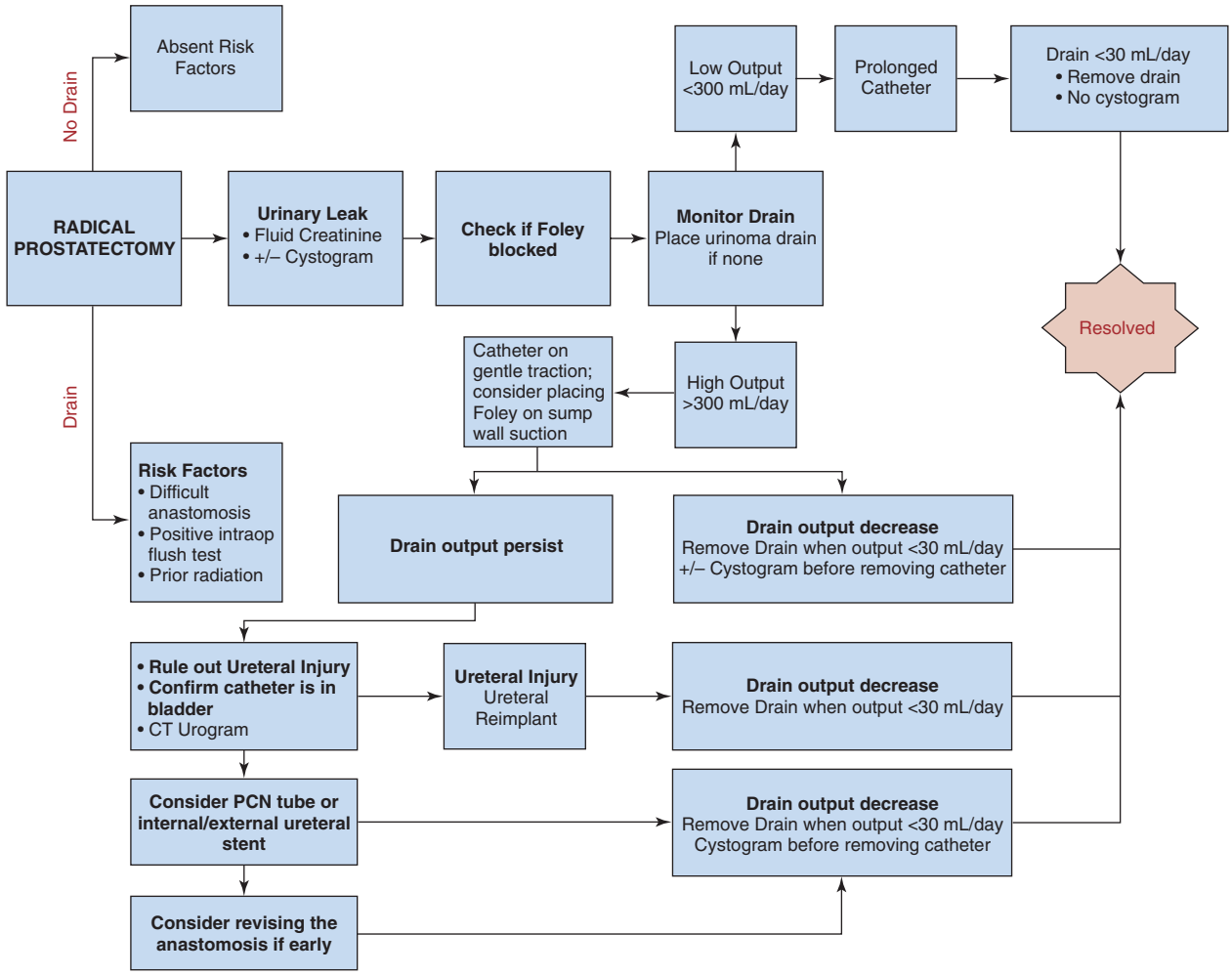


Figure 13.3 Treatment algorithm of urinary leak after radical prostatectomy.

Fortunately, the majority of urinary leak can be managed with prolonged Foley and pelvic drain without the requirement for additional maneuvers.[48,49] Less than 5% of patients may require additional percutaneous drainage of the uroperitoneum.[48]

If the leakage remains high despite the above maneuvers, the Foley catheter can be placed on gentle traction against the anastomosis. The drain output subsequently may be dependent on the closeness between the ureteral orifices and urethrovesical anastomosis.[68] If the ureteral orifices are situated far away from the urethrovesical line and there is profuse leakage, gentle traction or apposition of the catheter against the bladder neck can reduce leakage and external fixation may help.[68] If the ureteral orifices are close to the anastomosis, the Foley balloon can oppose the ureteral orifices or lie above the ureteral orifices and impair urinary drainage, thereby worsening leakage. Traction against this will only increase the urinary leak. As such, in this case, gentle radiologic guided mobilization of the catheter with deflation of the balloon and proper external fixation of the catheter can be done to avoid dislocation and allow improved drainage via the indwelling catheter.[44,68] Alternatively, 14-16Fr Cope loop nephrostomy tube can be placed as a urethral catheter to allow improved urinary drainage through several drainage holes.

In the presence of high-output leakage where the majority of urine is coming from the perianastomosis drain rather than per the catheter, CT urogram should be performed to rule out an iatrogenic ureteral injury and to ensure that the catheter balloon remains in the bladder. In cases of ureteral injury, a decision to do ureteral reimplantation or nephrostomy with delayed ureteral reimplantation is left up to the discretion of the surgeon, and no complication differences are seen with early versus delayed reimplantation,[83] although it is our practice to repair early. If no ureteral injury is thus identified and urinary leakage exceeds >1.5 L, revision of the anastomosis can be performed even up to POD 6–12.[47,48,69] This option should be reserved for rare circumstances.

Rather than a repeat revision of the anastomosis, several other options have been described as potentially effective. One option is to continue to observe the patient ensuring that all leaked urine is diverted effectively. This may be accomplished by leaving the JP drain or placing an additional drain under radiographic guidance.[49] Another approach described is a needle-vented suction of the Foley catheter.[84] The Foley catheter is connected to low wall suction at 15 to 20 mm Hg. To avoid continuous suction against the bladder mucosa, a sump is created by placing an 18-gauge angiocatheter needle in the tubing connecting the Foley to the wall suction. This technique allows a gentle vacuum to allow urine to preferentially drain through the catheter rather than leaking through the anastomosis. Another approach described is to divert all of the urine away by placing single J internal–external ureteral stents bilaterally. This allows all urine to become diverted and will minimize all urinary leakage.[69] A final approach described is to place either bilateral nephrostomy tubes to divert all urine or a unilateral nephroureteral stent, which can be placed on intermittent wall suction.[85]

Ultimately, the drain output is monitored daily. When the output decreases significantly, another fluid creatinine can be done to rule out any residual leak. The drain is subsequently removed and after a repeat cystogram has ensured healing, the Foley catheter can safely be removed.

Urinary Leak Following Urinary Diversions and Bladder Reconstruction

DEFINITION AND DIAGNOSIS OF URINARY LEAK

Compared to leakage after radical prostatectomy or partial nephrectomy, urine leak after urinary diversions has not been studied as extensively in the literature as a primary end point. Richard et al. defines a urine leak as elevated drain fluid creatinine level beyond POD 7,[86] while other studies define it as early as POD 1.[87–89] A small amount of urinary extravasation in the early postoperative period seems to be acceptable[90] and may resolve by POD 7 with adequate drainage.[87,91]

The study of choice to confirm laterality or location of leakage is a combination of CT urogram and loopogram/pouchogram.[88–90] However, while radiographic studies are more sensitive for a identifying a leak, they are generally done to localize the presence of a clinical leak. In a study by Ankem et al. on patients with continent urinary diversion, five of six leaks diagnosed with a pouchogram were clinically detectable.[92] In a study by Brown et al., of 15 urinary leaks, three were localized by CT urogram, 10 by CT conduitogram, and the remaining two on nephrostogram done at the time of percutaneous nephrostomy tube insertion.[88] Many patients with urine leak can also have an infected urinoma, and it is imperative to identify this early on CT imaging.[90,93]

SYMPTOMS OF URINARY LEAK

Two studies evaluated urinary leak as a primary end point and tabulated presenting symptoms.[88,89] In 21 patients, Hensle et al. showed ileus to be a presenting symptom of a leak in four (19%), urinary drainage from wounds in seven (33.3%), elevated BUN without increased creatinine in 20 (95.2%), and sepsis in 10 (47.6%).[89] In a study of 15 patients, Brown et al. indicated sepsis as a presenting symptom in eight (53.3%), increased drain output in six (40%), leakage from wound in five (33.3%), and decreased urine output in four (26.6%), with one asymptomatic patient diagnosed on a routine "stentogram" prior to removal of stent.[88] In other series, urinary leak is also associated with prolonged ileus and prolonged length of hospitalization.[93,94]

There appears to be a bimodal temporal presentation of urinary leak. In Hensle et al.'s study, 8 of 21 (38%) presented within the first 24 hours and 13 of 21 (62%) presented after POD 6.[89] Additionally, those who presented after POD 6 had worse outcomes. Brown et al. noted a median time to leak of 12 days, with 2 of 15 (13%) presenting within the first 6 days and 13 of 15 (87%) presenting after POD 6.[88] Patients who presented within the first few days postoperatively may represent technical errors. In the Brown et al.'s study, for the two patients who presented with early leak the sources were "technical construction of ureteroenteric anastomosis" in one and a stoma catheter perforating

staple line at the blind end of the conduit in another. On the other hand, those who presented after POD 6 may represent a manifestation of ischemic necrosis of the anastomosis.[91] As such urinary leak is also thought to be a risk factor for development of ischemic ureteroenteric stricture.[86]

Urinary leak has an adverse effect on mortality,[89,93] which may be due to multiorgan failure from concomitant sepsis[89,93,95] or may also be due to rapid cancer progression theorized to be a result of proinflammatory cytokines and suppressed antitumor inflammation response.[88] Sepsis is one of the more common causes of mortality following radical cystectomy and urine leak has been diagnosed up to 40% of septic patients who died within 30 days.[95] In the Hensle et al.'s study, alarmingly, 48% of patients with a urinary leak died perioperatively.[89] Additionally, mortality risks are also associated with elevated serum BUN, an indirect marker of urinary leak, where rates are 5.8% if BUN <30 and increase to 33.3% with BUN >100.[96]

INCIDENCE AND DIFFERENTIAL OF URINARY LEAK

The incidence of urine leak after ileal conduit ranges from 1.87% to 16%.[88,89,93,96,97] If limited to series with >500 patients, the incidence ranges from 1.87% to 2.57%.[89,96] In more than 60% of cases, leakage occurred from the ureteroenteric anastomosis, but it can also occur anywhere along the loop including the butt-end of the conduit.[89]

The incidence of urine leak after continent reservoir ranges from 2% to 12.8%.[90,98–101] Leakage can occur from the ureteroenteric anastomosis or from the extensive suture lines.

The incidence of urine leak after neobladder ranges from 2.1% to 11.6%.[102–105] If limited to series with >300 patients, the incidence ranges from 2.1% to 7.7%.[103,104] Leakage can occur from either the ureteroenteric anastomosis, the neovesico-urethral anastomosis, or anywhere along the extensive suture lines of the neobladder. In a series by Hautmann et al., the incidence of leakage per ileourethral anastomosis was 6.6% and from the ileoureteral anastomosis was 1.1%.[103]

RISK FACTORS OF URINARY LEAK

Evidence on the risk factors of urinary leak after urinary diversion is limited compared to the evidence of risk factors predisposing leakage after radical prostatectomy or partial nephrectomy. Studies describing risk factors are descriptive or achieve marginal statistical significance. No current multivariate model for urinary leakage exists following urinary diversion. Perhaps this is because urinary leak represents only a fraction of postoperative complications after cystectomy while it represents major complications after radical prostatectomy or partial nephrectomy. However, urinary leak after a diversion represents a greater concern as most are symptomatic and leakage can be a poor predictor of outcomes.

Risk factors for urinary leak after urinary diversion include palliative exenteration,[88,93] BMI >30,[99] prior pelvic radiation,[89,93,106] and cardiovascular medical history.[93] These factors may influence the vascular supply to the ureter or the ability to perform a high-quality diversion. Increasing medical comorbidities may also be associated with postoperative genitourinary complications, although no specific effect of comorbidities on urinary leakage is described.[107]

Urinary leakage is more common on the left ureter than on the right,[89] perhaps due to devascularization of left ureter with extensive mobilization or because the left anastomosis is more predisposed to be under tension. There do not appear to be any differences in urinary leak with interrupted or running suture anastomosis of the ureter.[108] Stomal edema/obstruction may increase the intraconduit pressure and increase the risk of ureteroileal anastomosis disruption.[91] Additionally, placement of a catheter postoperatively is the most common cause of iatrogenic injury to the stump of the conduit.[88] Extraluminal hematoma/seroma may also increase the risk of urinary leak by disrupting the blood supply.[91] Poor surgical technique (case reports of spermatic vein anastomosis to conduit)[109] and early learning curve can also predispose to a urinary leak. Recurrence of malignancy can be a risk factor for late presentation of urinary leaks.[110]

Prevention of Urinary Leak

Mattei et al. performed a prospective randomized trial on 54 patients with ileoureteral anastomosis to study the impact of perioperative ureteral stent on urinary leaks. The study revealed a significantly increased urinary leakage on POD 1 in the absence of stents, which becomes comparable by POD 3–7.[87] Additionally, stenting improved recovery of bowel function and reduced metabolic acidosis, perhaps by reducing the leakage in the early postoperative period. Another study confirmed an association of ileus in those with nonstented anastomosis.[94] A retrospective study by Beddoe et al. on patients with transverse colon conduits after pelvic radiation also demonstrated a significant decrease in urinary leakage after stented anastomosis (3% stented vs 18% nonstented).[111] On the other hand, Regan et al. illustrated a nonstatistically significant decrease in urinary leak rate in patients with stented anastomosis (0% stented vs 2.5%, $p = 0.09$).[112]

Management of Urinary Leak (see Fig. 13.4)

Management of urinary leak differs with respect to the etiology and timing. Patients who present with urinary leak within POD 1–6 are more likely to have an iatrogenic leak while those who present after POD 7 are due to poor healing and poor vascularization. As such, management differs in those who present early versus those whose presentation is delayed.

Open operative intervention may be favored in the very early postoperative period in patients with high-output urinary leakage, particularly when an iatrogenic injury is suspected. Endoscopic maneuvers including catheters per stoma, pelvic drains, and/or nephrostomy tubes may not lead to complete resolution of urinary leakage.

Of those who present in a more delayed fashion, early operative intervention <72 hours after diagnosis is

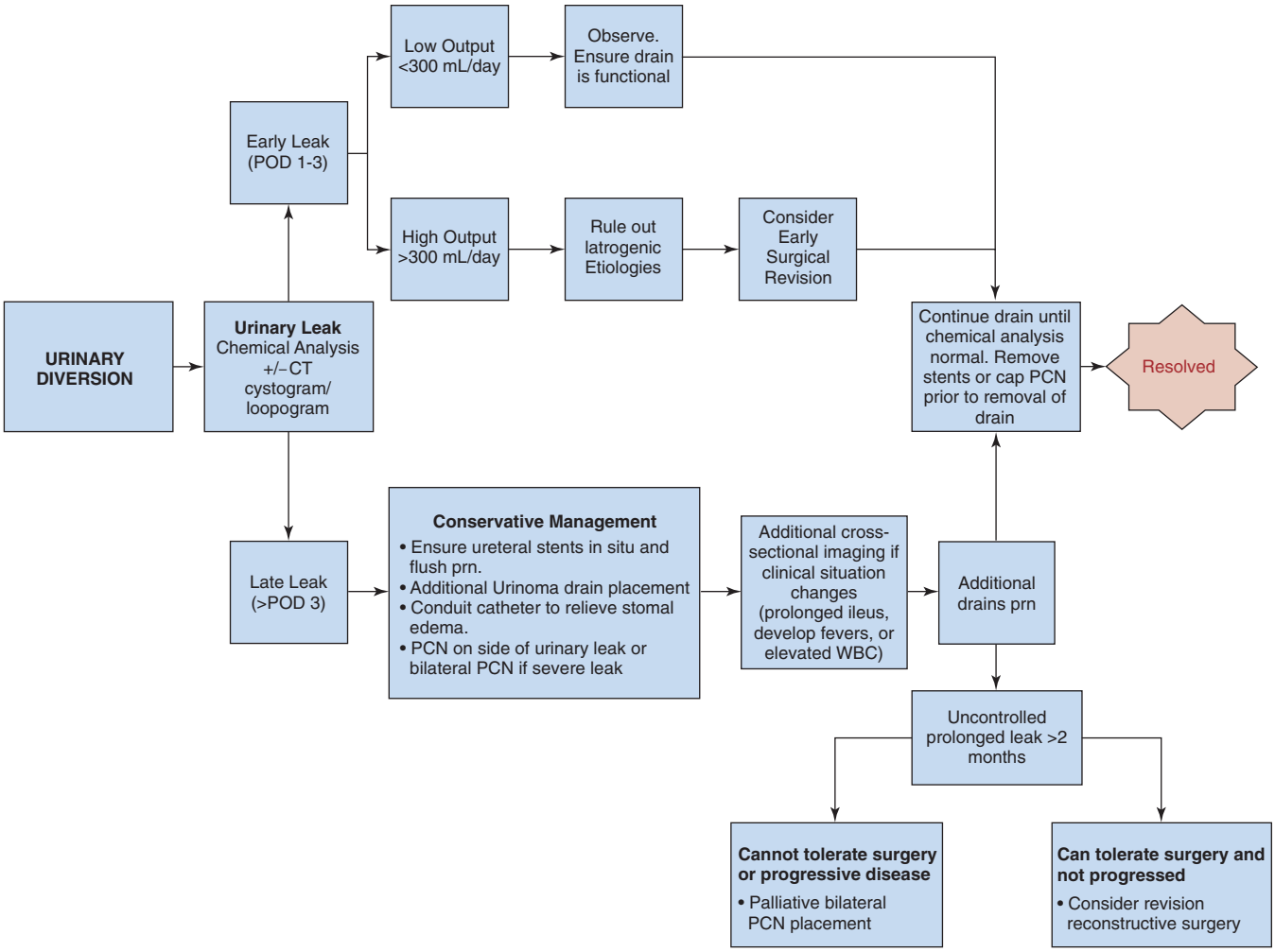


Figure 13.4 Treatment algorithm of urinary leak after urinary diversion.

indicated if conservative maneuvers fail. In a study by Hensle et al., of 12 patients managed with operative intervention, no patients died when explored within 72 hours, while 5 of 6 died when exploration was delayed until after 72 hours. Although provocative, case selection may have been an issue.[89] Additionally, 4 of 9 patients survived when managed nonoperatively (intraabdominal drain and drain per stoma). Fortunately, since the Hensle et al. study, endoscopic procedures (nephrostomy tubes and percutaneous urinoma drain) in addition to the antibiotics have augmented the armamentarium of conservative management.

Initial conservative maneuvers include placing a catheter in the stoma (with precaution due to the possibility of iatrogenic stomal injury) and ensuring that the intraabdominal drain is taken off suction and placed on gravity. If a urinoma collection is seen on cross-sectional imaging, we also recommend placing a CT-guided percutaneous drain within it and treating the patients with antibiotics if infection is suspected. However, if, despite these maneuvers, a clinically symptomatic urine leak persists, we recommend placing a nephrostomy tube on the side of the ureteroenteric leak. A "stentogram" or nephrostogram may also be performed at the time of placing a nephrostomy tube to confirm laterality. If no stent is present at this time, an attempt to stent across the ureteroenteric anastomosis in an antegrade fashion can be made.

In the Brown study, of 15 patients with a urinary leak, 2 patients with early presentation of urinary leak underwent early revision of the diversion, 3 patients were managed with a catheter in the stoma or JP drain, 11 with radiological diversion including nephrostomy tubes, and 1 with late open revision.[88] Of 11 patients managed with radiological diversion, 7 patients healed with a nephrostomy tube in place for a median duration of 40 days (range 21–57), 3 failed to heal after prolonged duration and developed progressive disease, and 1 underwent late revision.

Despite having a leak, many patients may not be in optimal condition to undergo an open revision. In these patients, bilateral nephrostomy tubes may be considered to divert all urine as a palliative measure. In one case report, a VAC therapy was also employed to close the leakage in addition to bilateral nephrostomy tubes.[113] The VAC tube was inserted through the abdominal wound and positioned at the leakage site. The suction was adjusted to 125 mm Hg, and after 32 days of VAC therapy, the urinary leakage resolved. In another study, angioplasty balloon catheters were deployed in the distal ureters to divert all urine per nephrostomy tubes.[114]

Once the urinary leak is effectively controlled, repeat fluid creatinine of the urinoma drain or intraabdominal drain should be done. If a nephrostomy tube is placed, a nephrostogram can be done periodically as clinically indicated to ensure resolution of the urinary leak. If no leakage is documented, nephrostomy tubes are capped and drain outputs are monitored to ensure that the leakage has not resumed. The nephrostomy tubes are then removed followed by the drain removal.

Urinary Leak Following Miscellaneous Procedures

URETERAL RECONSTRUCTION

Outcomes after ureteral reconstruction (uretero-ureterostomy or ureteral reimplant) come primarily from the transplant literature. Urine leak after a renal transplant can occur from multiple sites, including the upper tract, or ureteroneocystotomy site. Upper tract leakage may be due to segmental infarction in patients with injured accessory renal artery or due to ligation of a polar artery.[115] Urinary leakage is diagnosed clinically initially and confirmed on CT urogram or renal ultrasound. Renal ultrasound is generally preferred after transplant rather than a contrast-based study.

The incidence of a urinary leak can range from 0% to 9.3% of cases.[116] In a meta-analysis of 1154 renal-transplant patients from seven studies, the overall incidence of urinary leak was 3.1%.[117] In a study of 677 patients undergoing ureteroneocystotomy and 14 undergoing uretero-ureterostomy, the incidence of anastomotic urinary leakage, as opposed to upper tract leakage, after ureteroneocystotomy was 1.47% and after uretero-ureteral anastomosis was 7.1%.[118] Another study of 166 patients undergoing uretero-ureteral anastomosis after transplant suggested an anastomotic leak rate of 4.2%.[119]

Two prospective randomized trials between transvesical (Politano-Leadbetter) or extravesical (Lich-Gregoire) ureteroneocystotomy techniques indicate no difference in urinary leak rate,[120,121] while retrospective studies suggest an increased rate with transvesical approach due to leakage from cystotomy site.[118,122] Among the extravesical approaches, the Lich-Gregoire technique demonstrated a lower rate of urinary leakage compared to U-stitch techniques due to lack of mucosal-mucosal anastomosis in U-stitch technique.[123,124] Retrospective studies suggest no differences between refluxing and antirefluxing techniques.[125–127] Male gender has a higher incidence of urinary leakage, perhaps due to high-pressure voiding.[128]

Ureteral stents have not been consistently used at the time of ureteral reimplant in the transplant literature. In a large Cochrane collaboration meta-analysis, only 50.8% were stented at the time of transplant, and stenting reduced the rates of urinary leakage with a hazard ratio 0.29 (0.12–0.74).[117] Omental wrap has also been suggested to reduce the rates of urinary leakage, although the evidence for this is not strong.[129–131]

Conservative management of a urinary leak following any ureteral reimplant or primary repair includes placement of an indwelling Foley catheter to reduce urine refluxing up the ureter and ensuring that the stent is across the anastomosis. If an intraabdominal drain is in place, suction can be removed from the drain. The drain is maintained until low urine output is seen. If, despite the stent and Foley catheter, significant and prolonged drainage is seen, then a nephrostomy tube may be placed. For upper tract leak from ischemic calyceal necrosis after a transplant, a nephrostomy tube may be needed to ensure adequate drainage.[115] Before removal of any drains either an antegrade or retrograde pyelography can be done to illustrate the resolution of any urinary leaks.

If despite all endoscopic measures, urine leak continues, operative interventions include reconstruction, re-do ureterovesical reimplantation (may need psoas hitch or broari flap), pyelovesicostomy if bladder is adjacent to transplanted kidney, ileal interposition or nephrectomy. Between 40% and >75% of patients are managed with operative intervention.[119,132] in the transplant literature, although it is not known what proportion would have been salvaged with the further use of a nephrostomy tube or perioperative ureteral stents.

PYELOPLASTY

Urinary leak after pyeloplasty typically occurs at the site of the ureteropelvic anastomosis. Urinary leak is generally diagnosed clinically due to an increased drainage with chemical confirmation of leak. In a meta-analysis of 12 studies, the incidence of urinary leak following robotic, laparoscopic and open pyeloplasty was 2.92%, 2.75%, and 1.92%, respectively.[133] Han et al. performed a multivariate analysis to identify factors associated with the need for additional ureteral stenting in pediatric patients undergoing unstented pyeloplasty.[134] Of 285 pyeloplasties performed, 28 needed ureteral stent at a median of 0.8 months (range 0.3–1.6) and in 26 cases, urinoma formation was an indication for a stent. Preoperative differential renal function >60% in the obstructed kidney was an independent factor associated with a need for postoperative stent. Gender, laterality, age, and preoperative hydronephrosis were not associated with a need for stent.

In multiple studies, pyeloplasties performed with either intraoperative PCN or a stent decreased the risk of postoperative urinary leak.[135–137] In a population-based study consisting of 2435 pyeloplasty patients, which compared patients with and without intraoperative stent/PCN placement, those with intraoperative stent/PCN use had clinically significant urinary leak requiring the need of postoperative stent/PCN placement.[137]

When urinary leak is diagnosed after pyeloplasty, management options include prolonged surgical drainage with or without urethral catheter, stent replacement/repositioning, or an immediate nephrostomy tube placement. Conservative management with reinsertion of a urethral catheter, drainage, and time is often successful in the absence of obstruction. The drain is removed when output ceases.[138] Several other studies on stented pyeloplasty support resolution of leak with prolonged duration of drain.[139,140]

Conversely, Cadeddu et al. favors immediate placement of a nephrostomy tube to stop leakage across the anastomosis.[141] In their opinion, persistent exposure of perianastomotic tissue to urine may induce fibrosis and can compromise

the success of a pyeloplasty. In their series of 125 patients, 6 patients developed a urinary leak and were managed with placement of a PCN tube at a median of 4.5 days (range 2–7). In each case, drainage stopped upon PCN placement, allowing the surgical drain to be removed within the next 48 hours. The PCN was removed after an antegrade nephrostogram showed resolution of the leak. The PCN was placed for median 9.5 (range 5–42) days.[141]

Conclusions

Urinary leak is one of the common complications of urological surgeries. Patients may present with a spectrum of signs and symptoms or may be completely asymptomatic depending on the size, extent, anatomy, and timing of the leak. In clinically significant cases, urinary leak may lead to ascites, electrolyte abnormalities, ileus, or sepsis. Sepsis is among the most concerning sequelae of a urinary leak and is associated with poor survival. Prevention strategies include intraoperative technical fastidiousness, placement of a stent across any urinary anastomosis including a catheter in the case of urethrovesical anastomosis, or a stent in the case of pyeloplasty or ureteral reimplant. All management strategies involve maximal drainage of the leak, which is often followed by delayed but spontaneous closure. Often a prolonged surgical drain with the tincture of time is sufficient to bring about such closure. At other times a drain may be placed within the urinary tract at an upstream location to a urinary leak (PCN for ureteral anastomotic leakage, bilateral PCN for urethra-vesical leakage, and ureteral stent for leakage from partial nephrectomy defect). Downstream obstruction must always be clinically assessed and eliminated. If endoscopic measures fail, operative intervention may become necessary but in stable patients should be delayed in an attempt to achieve spontaneous closure. Management of urinary leakage can be frustrating both for the physician and for the patient, leading to a prolonged course of hospitalization and recovery, and adequate communication and expectations are essential.

References

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Chapter 13 Questions

1. Which of the following signs/symptoms are consistent with intraperitoneal urinary leak?
   a. Hyponatremia
   b. Hyperkalemia
   c. Rising creatinine with elevated BUN levels
   d. Progressive abdominal distention followed by peritonitis
   e. All of the above

Case Study 1: Urinary Leak After Partial Nephrectomy

A 50-year-old female presented with gross painless hematuria in the absence of prior history of genitourinary malignancy or stones. Her prior medical history was unremarkable. She denied smoking. Her exam was unremarkable. Her glomerular filtration rate was normal.

She underwent CT abdomen/pelvis with and without contrast as part of the workup with the imaging as follows (Case Fig. 13.1).

1. Which of the following is a risk factor for urinary leak in this patient?
   a. Endophytic tumor
   b. Nearness to collecting system
   c. Renal pelvic score >50%
   d. All of the above
   e. Option b and c

CT scan demonstrated a nephrometry score 11 tumor, clinical T1b. Options were discussed and the patient opted for an open left partial nephrectomy.

A flexible cystoscopy was performed while the patient was positioned supine after induction of anesthesia. A left open-ended ureteral access catheter was placed. The patient was then positioned into a lateral decubitus position and underwent an uncomplicated partial nephrectomy. A complex renal hilum was encountered with multiple renal vessels including an accessory upper pole artery. A bulldog clamp was placed across the isolated accessory renal artery and a Satinsky clamp was used for hilar control.

The renal mass was then resected. Collecting system entries were identified and over-sewn under loop magnification. Methylene blue was injected per ureteral stent to identify any other entries. The repair appeared watertight. The renorrhaphy was performed in a standard fashion. Total warm ischemia time was 47 minutes and 37 seconds. A JP drain was placed in the retroperitoneum.

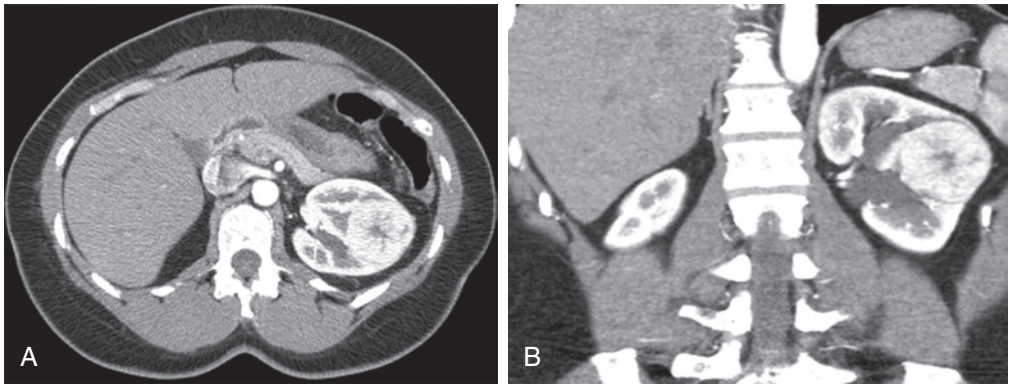
The patient's postoperative course was uneventful. She was discharged home on POD 4 with modest JP outputs of approximately 100 mL/day. She was seen in clinic on POD 7. Her JP drain was producing <30 mL/day. A CT urogram with excretory phases indicated no urinary leakage, and her drain was removed.

Over the next 24 hours, the patient developed increasing abdominal pain, fevers, and malaise. She was admitted for further evaluation. Her WBC at admission was 33. Cultures were sent. A CT scan was performed that revealed an ipsilateral pleural effusion, a perinephric collection with air–fluid levels, and a urine leak. She subsequently underwent a left pleural drain as well as placement of left perinephric drain collection. Fluid chemical analysis revealed elevated creatinine to 65.5 mg/dL. Fluid culture grew *Serratia* sensitive to fluoroquinolone. Her fevers and WBC improved on antibiotics. Her drain output continued to be steady at approximately 150 mL/day over the next 2 weeks.

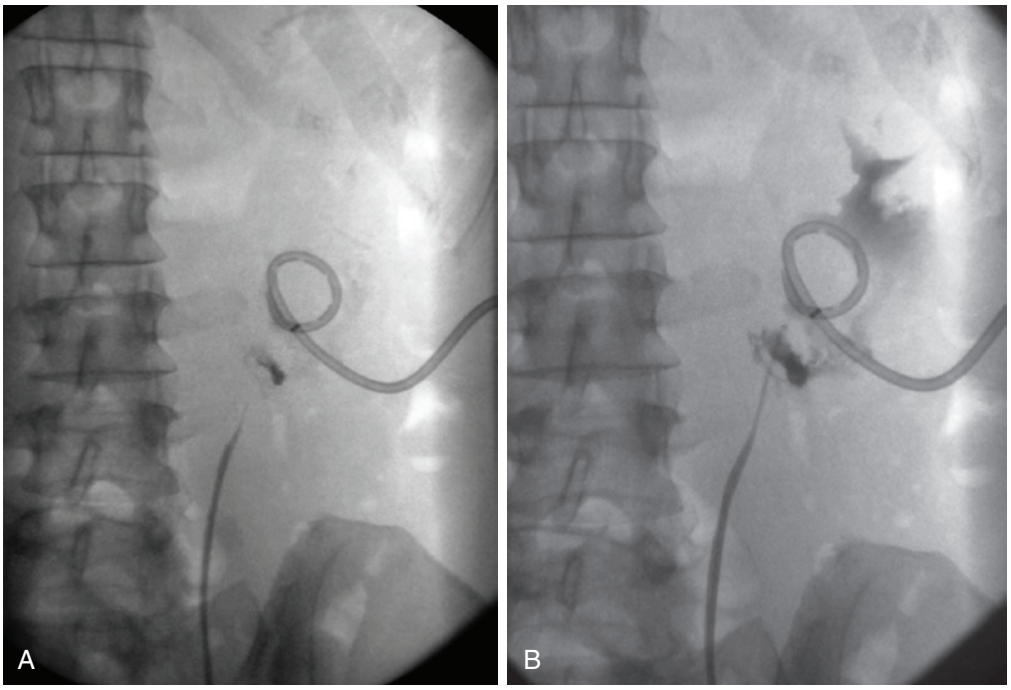
2. Which of the following is the next step in a patient with persistent urinary drainage after partial nephrectomy?
   a. Radical nephrectomy
   b. Nephrostomy tube
   c. Retrograde pyelogram/stent placement
   d. Continue to observe
   e. Open exploration with re-do renorrhaphy

Given her persistent JP output, the patient underwent left retrograde pyelogram (Case Fig. 13.2) noting leakage of contrast from the proximal ureter. Attempts at retrograde stenting were unsuccessful and resulted in increased JP output to approximately 400–600 mL/day. Given distal obstruction a nephrostomy tube was placed (Case Fig. 13.3). At least two failed antegrade and retrograde attempts were made endoscopically to place a stent across the leakage.

The patient was hospitalized twice in the interim with pyelonephritis and urinary sepsis.



Case Figure 13.1



Case Figure 13.2



Case Figure 13.3

3. In this patient who failed endoscopic attempts following partial nephrectomy, what options remain for management of a urinary leakage?
   a. Ureteroureterostomy (open reconstruction)
   b. Ileal interposition
   c. Completion nephrectomy
   d. Autotransplant
   e. All of the above

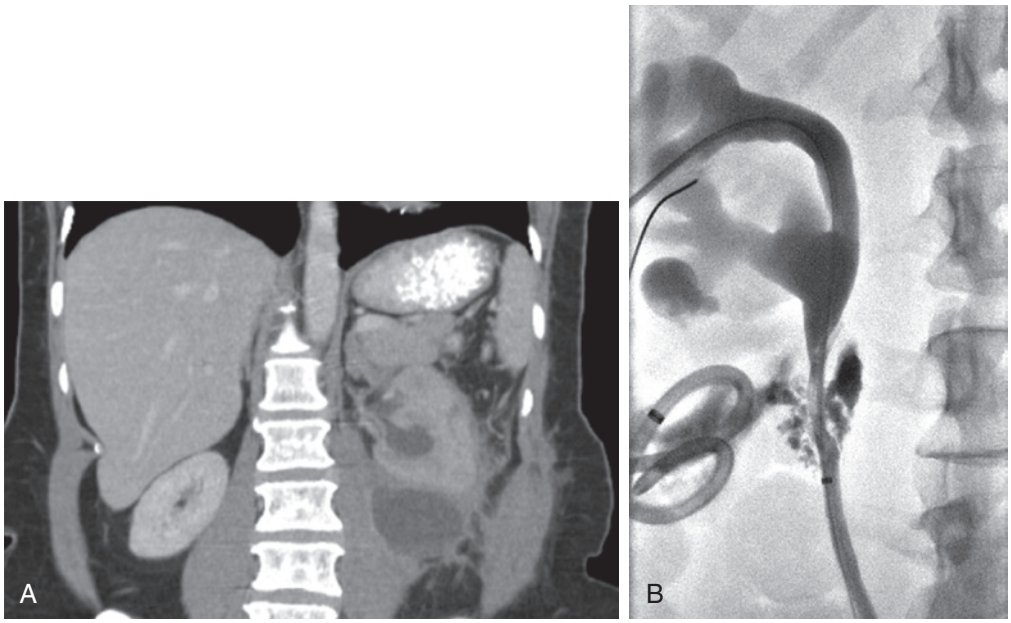
All of the above options were discussed with the patient. She elected to proceed with attempted reconstruction. Six months following her initial surgery, she was taken to the operating room for attempted robotic ureterolysis, ureteroureterostomy and omental flap. Despite a difficult dissection, uretero-ureterostomy was performed, leaving both a nephrostomy tube and ureteral stent in place in addition to a JP drain. She was discharged home on POD 4 with a JP drain, PCN tube to gravity, indwelling ureteral stent, and a Foley catheter to maximize drainage. Her drain output was minimal at about 10–30 mL/day. Her Foley catheter was removed POD 9 from reconstruction. On POD 16, her JP drain was removed, and PCN was left on gravity. On POD 23, antegrade nephrostogram was performed, which revealed no urinary leakage. Subsequently, PCN was capped for another week and was then removed on POD 30. The stent was left in place for complete healing.

One month later she presented with fevers, chills, and leukocytosis. Imaging noted a perinephric abscess. Percutaneous drainage revealed a fluid creatinine of 10.8. Cultures grew candida. Antegrade nephrostogram demonstrated a recurrent urinary leak at the site of anastomosis despite a well-positioned ureteral stent (Case Fig. 13.4). Delayed CT imaging showed delayed nephrostogram in the left kidney, suggesting reduced function.

Given her prolonged course, she elected radical nephrectomy rather than open repeat reconstruction and had an uneventful postoperative course.

Case Study 2: Urinary Leak After Radical Prostatectomy

A 66-year-old male presented with a PSA of 8.3. Biopsy noted Gleason 6 prostate cancer. His AUA symptom score was 14 with a QOL score of 2–3 despite alpha blockade. He



Case Figure 13.4

had baseline urinary dribbling, frequency, and occasional urge incontinence. His SHIM score was 17. On exam, he had an enlarged prostate measuring approximately 80 g.

He elected to undergo robotic radical prostatectomy. The procedure was the tenth procedure done independently by the surgeon. Intraoperatively, an enlarged trilobar prostate was encountered, which resulted in an abnormally large bladder neck complicating the urethrovesical anastomosis. The reconstruction was time consuming and technically difficult. However, an intraoperative flush test was deemed acceptably watertight. A Blake drain was left to suction at the end of the procedure.

1. Which of the following is not a risk factor for urinary leak after radical prostatectomy?
   a. Early learning curve
   b. Technically complicated anastomosis
   c. Imperfect intraoperative flush test
   d. Surgical approach (open vs robotic)
   e. Increased blood loss

Postoperatively, drain output was approximately 200 mL/day. Additionally, he developed progressive abdominal distention and ileus and was started on total parenteral nutrition (TPN). By POD 7 he developed signs and symptoms of peritonitis with high fevers. Blood, urine and fluid cultures were all negative. His serum creatinine was noted to be elevated to 1.6 from a baseline of 0.8. He became hyponatremic with elevated BUN levels.

A drain creatinine was consistent with urine at 75.9 mg/dL. Cystogram indicated a urinary leak lateral to the right posterior bladder neck. A CT urogram done to rule out ureteral injury indicated intact drainage from the ureters to the bladder but a leak again posterior to the right bladder neck. Additionally, the urinary leak extended into the intraperitoneal cavity (Case Fig. 13.5).

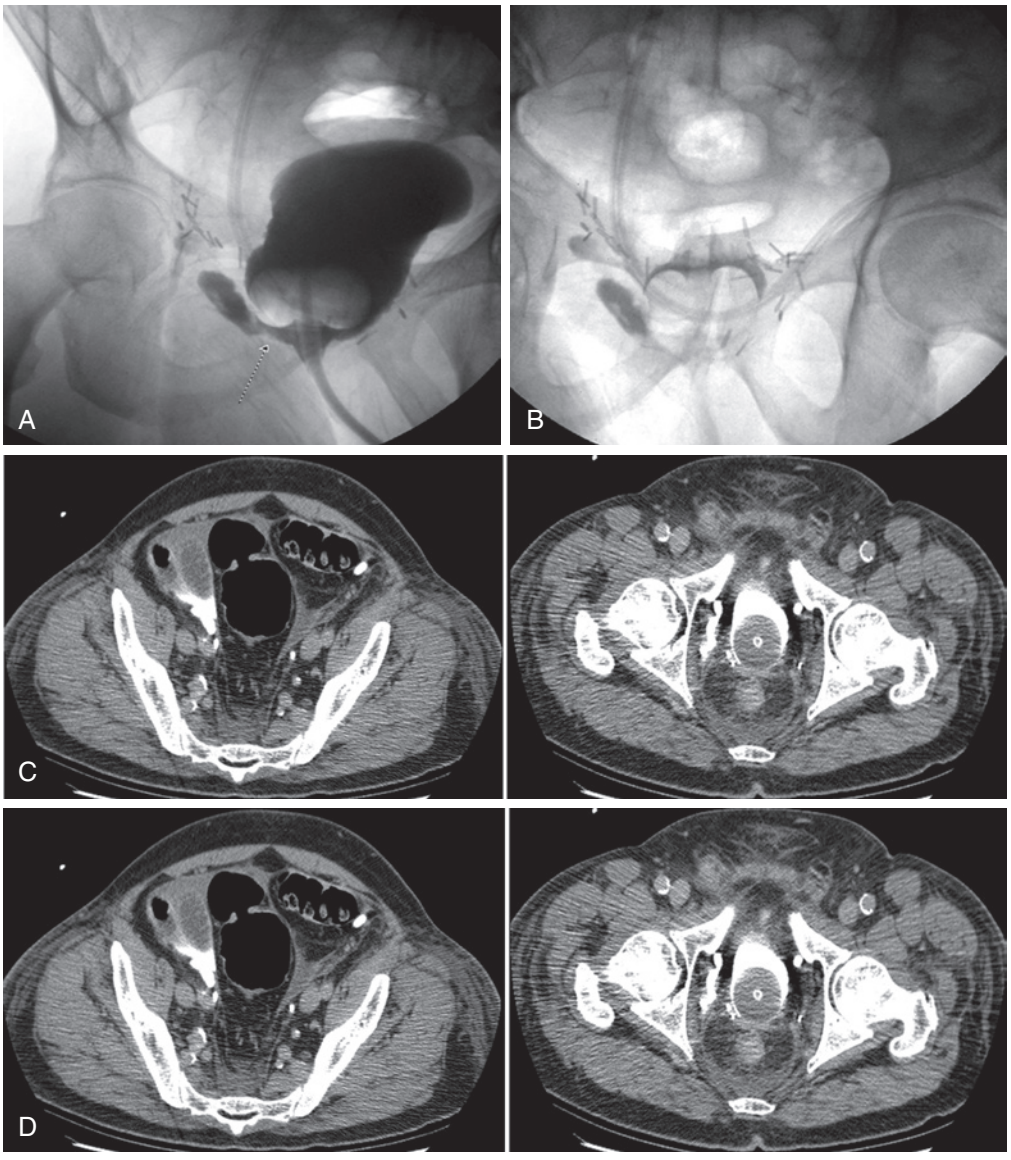
2. Which of the following is not a characteristic of clinically significant anastomotic leak?
   a. Those that extend into intraperitoneal cavity
   b. Prolonged ileus
   c. Urinary sepsis
   d. Leakage that is drained completely by the pelvic drain
   e. Significant electrolyte abnormalities

As the leak was close to the right posterior bladder neck, the decision was made to place a right nephrostomy tube. His peritonitis improved. His ileus progressively resolved. The Blake drain output slowed, and he was discharged home on POD 17 without a drain but with right PCN and Foley catheter.

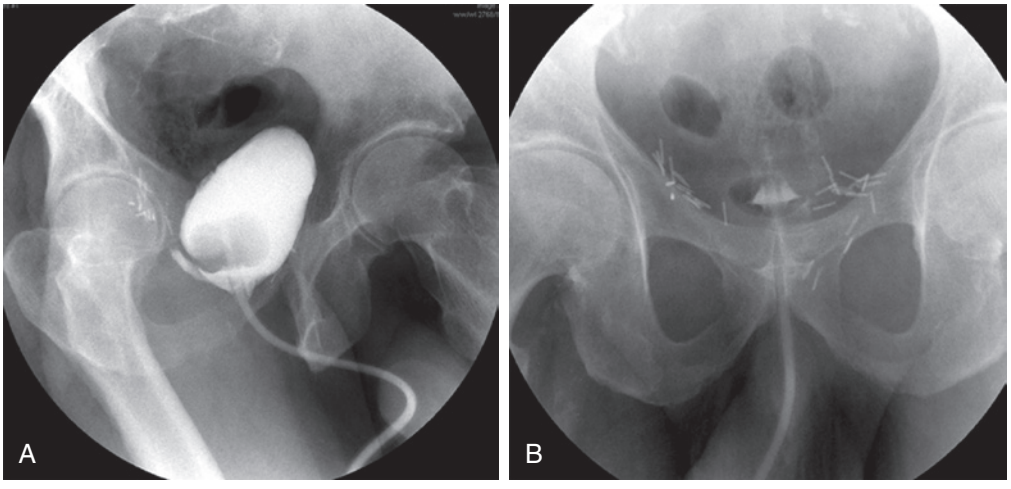
He was seen in clinic on POD 25 with a cystogram. Cystogram showed resolution of urinary leak, and the Foley catheter was removed (Case Fig. 13.6). His PCN was capped. On POD 33 he underwent a nephrostogram prior to removal of the PCN tube.

By his 6-month follow-up, he was not using any pads and denied any incontinence. He did not gain spontaneous recovery of sexual function.

3. Which of the following is true about urinary continence and risk of bladder neck contracture (BNC) after prostatectomy complicated by a urinary leak?
   a. Long-term urinary continence is compromised, but risk of BNC is unchanged
   b. Return to continence is delayed but usually complete, and risk of BNC may be elevated
   c. Long-term urinary continence is compromised, and risk of BNC is elevated
   d. Return to continence is delayed, and risk of BNC is elevated
   e. Return to continence is same and risk of BNC is minimal



Case Figure 13.5



Case Figure 13.6

Case Study 3: Urinary Leak After Urinary Diversion

A 56-year-old male former smoker was diagnosed with muscle-invasive bladder cancer and underwent neoadjuvant chemotherapy. He was hoping to avoid subsequent cystectomy and despite several opinions elected to delay pelvic exenteration. He recurred locally in the bladder within the next 6 months and subsequently agreed to undergo cystectomy with creation of ileal neobladder. CT scan noted interval development of hydronephrosis on the right from tumor obstruction with a creatinine of 1.67. Preoperative serum albumin was 2.1 g/dL, suggesting preexisting malnutrition from disease.

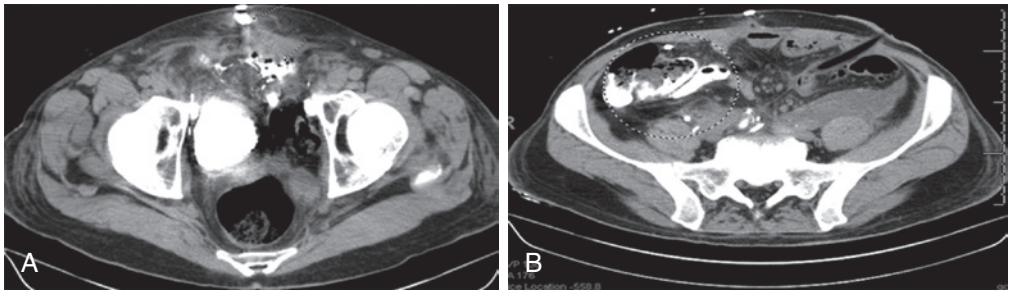
He underwent radical cystoprostatectomy, bilateral pelvic lymphadenectomy, and creation of Studer neobladder with an EBL of 1800 mL requiring 2 units pRBC intraoperatively. A large omental flap was interposed between the neobladder and the small bowel anastomosis. An SPT and Foley catheter were left to drain the neobladder. He also had internal–external ureteral stents for full urinary diversion and a pelvic drain.

His postoperative course was complicated by prolonged ileus requiring TPN and subsequent deep vein thrombosis (DVT) and clinically symptomatic pulmonary embolism (PE) requiring anticoagulation and IVC filter placement on POD 15. His albumin levels declined to 1.2, suggesting worsening nutrition. He was maintained on TPN until he was tolerating regular diet by POD 20. He was ready to be discharged on POD 21, but on the day of discharge he had significant diarrhea and appeared to have profuse clear drainage from the wound. Irrigation of the Foley catheter would increase drainage per wound.

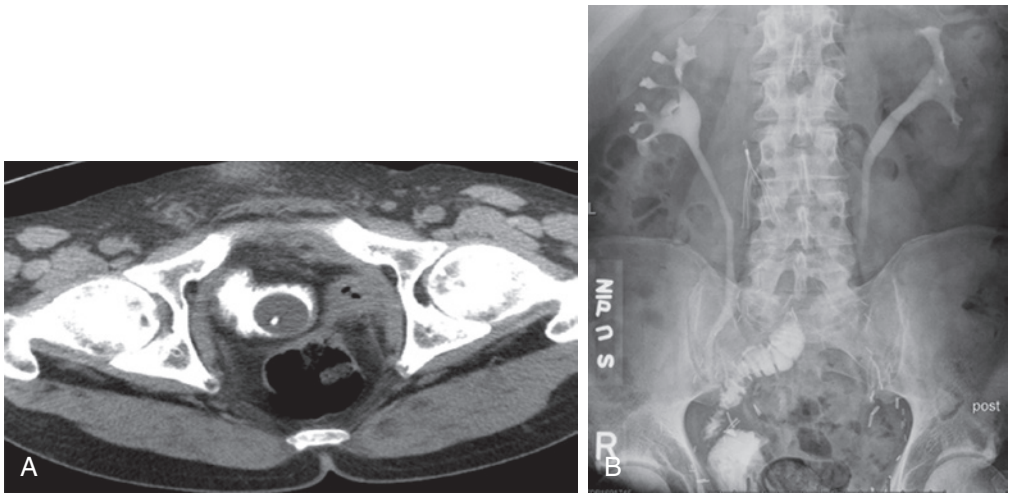
CT cystogram was done at this point, which indicated a neovesico-cutaneous fistula as well as a fistula between the small bowel anastomosis and neobladder (Case Fig. 13.7). General surgery consult was obtained for assistance in management of the entero-neovesical fistula. The overall impression was to conservatively manage him at this point until his nutrition status improved to the point where he could tolerate entero-neovesical fistula takedown and possible conversion of the neobladder to an ileal conduit.

He was restarted on TPN. Bilateral nephrostomy tubes were placed to completely divert the urine from the pouch. He became uroseptic twice and was treated on IV antibiotics for *Escherichia coli* and *Enterobacter* bacteremia. His leakage from the wound resolved, and the wound appeared to heal well. He became stable by POD 35 and was then advanced to a clear liquid diet with TPN, which he continued to tolerate. The majority of his urine output was from PCN and ureteral stents with small volumes from the Foley catheter. He was discharged home on POD 42 on TPN/clear liquids with Foley catheter, pelvic drain, bilateral PCN, ureteral stents, and aggressive wound care.

On POD 71 his pelvic drain was removed. Ureteral stentograms were done that showed no leakage, and the stents were removed. On POD 87 CT cystogram was repeated, which illustrated resolution of both neovesico-cutaneous and neovesico-enteral fistula (Case Fig. 13.8A). He was



Case Figure 13.7



Case Figure 13.8

then advanced to a full liquid diet. His TPN was weaned and he was advanced to regular diet. His nephrostomy tubes were capped for a week and were removed after nephrostogram illustrated urine draining into the bladder with no urinary leakage. A repeat cystogram was done on at 3 months postoperatively (Case Fig. 13.8B), which illustrated no urinary leakage or fistula and urine refluxing up both ureters. His Foley catheter was then removed and he began voiding spontaneously.

At 1-year follow-up, he has no spontaneous sexual recovery and remains with significant stress incontinence and is contemplating correction.

1. Which of the following is a risk factor for delayed urinary leak in this patient?
   a. Poor nutrition
   b. Omental flap
   c. Anticoagulation
   d. All of the above
   e. Option a and c

2. Urinary leakage is associated with all of the following except?
   a. Elevated BUN without necessarily an increase in creatinine
   b. Urinary drainage from wounds
   c. Prolonged length of hospitalization
   d. No effect on mortality
   e. Urinary Sepsis

3. Management of urinary leakage can:
   a. Be frustrating for the physician and the patient
   b. Require adequate communication of expectations
   c. Involve maximal drainage of the leak, which is often followed by delayed but spontaneous closure without requiring surgical re-exploration in the majority of patients
   d. All of the above
   e. Option a and b

Answers

1. **e.** Intraperitoneal urinary leak is often not contained and can present in delayed fashion with increasing abdominal distension, ascites, or progressive azotemia. Electrolyte abnormalities such as hyponatremia, hyperkalemia, elevated serum creatinine, increasing blood urea nitrogen, and metabolic acidosis are present. Urinary leak can be a nidus for infection and can lead to peritonitis.

CASE STUDY 1: URINARY LEAK AFTER PARTIAL NEPHRECTOMY

1. **d.** Risk factors for urinary leak after partial nephrectomy include endophytic tumor, intrarenal pelvis (Renal pelvic score > 50%), and nearness to the collecting system.
2. **c.** When a patient with partial nephrectomy presents with symptomatic urinary leak (increased JP drain output, UTI, pleural effusion, infected fluid collection), it is most appropriate to ensure a perinephric drain is patent and place a ureteral stent. The combination of ureteral stent with intraabdominal JP drain may result in resolution of the leak in the vast majority of patients.
3. **e.** In this patient where the leakage is from the ureteropelvic junction (likely from the Satinsky clamp placement across the entire hilum including proximal ureter) with failed endoscopic management, reconstructive procedures such as pyeloplasty, ureteroureterostomy, ileal interposition, completion nephrectomy or autotransplant should be considered.

CASE STUDY 2: URINARY LEAK AFTER RADICAL PROSTATECTOMY

1. **d.** Early learning curve, technically complicated anastomosis, imperfect intraoperative flush test and increased blood loss/hematoma are all risk factors for urinary leakage after radical prostatectomy. There has been no difference in leakage rate with open versus minimally invasive approach or by extraperitoneal versus intraperitoneal surgical approach.
2. **d.** Clinically significant anastomotic leaks after radical prostatectomy are those that extend into intraperitoneal cavity and show signs and symptoms of urinary leakage which may include ileus, electrolyte abnormalities, or urinary sepsis if they get infected. Leakage that is drained completely by the pelvic drain generally does not present with any clinical symptoms and may resolve with observation.
3. **b.** Prolonged and extensive urinary leakage, resulting from an anastomotic gap, may cause scarring leading to healing by secondary intention. Thus, risk of bladder neck contracture is elevated. Return to continence is usually delayed but overall continence rates are similar.

CASE STUDY 3: URINARY LEAK AFTER URINARY DIVERSION

1. **a.** Poor nutrition and vascular compromise/ischemia are risk factors for delayed urinary leakage. Omental flap or need for anticoagulation should not effect the urinary leakage.
2. **d.** Studies have shown that urinary leakage can have adverse effect on mortality. This may be due to multiorgan failure from concomitant sepsis or may also be due to rapid cancer progression theorized to be a result of pro-inflammatory cytokines and suppressed antitumor inflammatory response.
3. **d.** Management of a urinary leak can be anxiety provoking and frustrating for both the physician and the patient. It requires adequate communication of expectations. Further urinary diversion with additional drains or nephrostomy tubes may be needed. However, maximal drainage of the leak generally is followed by delayed, but spontaneous, closure without requiring surgical re-exploration.

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14 Management of Ureteral Injury

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CHAPTER OUTLINE

Introduction
Anatomy
Etiologies of Ureteral Injury
Diagnosis
Timing of Repair
Preoperative Management
Strategies for the Management of Ureteral Injuries
Endoscopic Repair
Proximal Ureteral Repair
Midureteral Repair
Distal Ureteral Repair
Long-Length Ureteral Repair
Other Considerations
Summary
Chapter 14 Questions and Answers

KEY POINTS

1. An understanding of the anatomy of the ureter, including its course and blood supply, is necessary for successful management of ureteral injury.
2. Timely and accurate diagnosis of the ureteral injury, including the etiology and extent of injury, is critical for minimizing sequelae and facilitating repair.
3. The key principles of ureteral reconstruction include isolation of viable tissue, tension-free anastomosis, and intraluminal stent drainage in the short-term postoperatively.

Introduction

When injury to the ureter occurs, the passage of urine from the kidney to the bladder is disrupted. Timely recognition is important to avoid renal deterioration and morbidity. Management of ureteral injury is often elective, but may require emergent intervention. Therefore it is important that the urologic surgeon is prepared to manage injuries that may occur along the entire length of the ureter. The primary aims of management include restoring quality of life, preserving renal function, and minimizing complications including urinoma, fistula, infection, and stricture.

Anatomy

Between the renal pelvis and the bladder, the course of the ureter travels through the retroperitoneum posterior to the colonic mesentery. The ureter can be divided into the upper, middle, and lower segments. From proximally to distally, the 22- to 30-cm ureter travels anterior to the psoas muscle, under the gonadal vessels as they cross from medial to lateral about 2–3 cm below the inferior margin of the kidney, over the iliac vessels at the bifurcation of the common iliac artery, and into the pelvis, where it enters the bladder trigone. Two good locations to identify the ureter are over the iliac bifurcation and lateral to the gonadal vessels at the level of the lower pole of the kidney. The blood supply of the ureter is segmental and enters the proximal ureter medially and pelvic ureter laterally (Fig. 14.1). The vascular plexus of the ureter is located in the adventitia. Branches that supply the ureter are difficult to visualize and arise from the renal, gonadal, lumbar, aorta, and iliac arteries. The layers of the ureter include the urothelium, lamina propria, smooth muscle (longitudinal and circular), and surrounding adventitia.

Etiologies of Ureteral Injury

Ureteral injuries can be classified by their etiologies, which most commonly include iatrogenic causes[1] or blunt or penetrating trauma.[2]

Iatrogenic causes often include endoscopic trauma during the management of stone disease.[1] Urinary stone impaction may predispose to additional injury to the ureter,[3] leading to submucosal, extraluminal, or a Steinstrasse pattern that may eventually lead to the development of a ureteral stricture. Ureteroscopic misadventure may lead to perforation, avulsion, or mucosal tears. Forgotten or neglected encrusted ureteral stents may also lead to ureter stricture. A history of retroperitoneal or pelvic radiation for malignancy may predispose to ureteral stricture. Complications related to gynecologic surgery including hysterectomy may lead to ureteral ligation or injury that may be initially recognized or at a delayed presentation (Fig. 14.2).[4] Abdominoperineal resection, hemicolectomy, and other colorectal procedures may predispose to distal ureteral injuries. Neurosurgical and orthopedic procedures of the spine may also

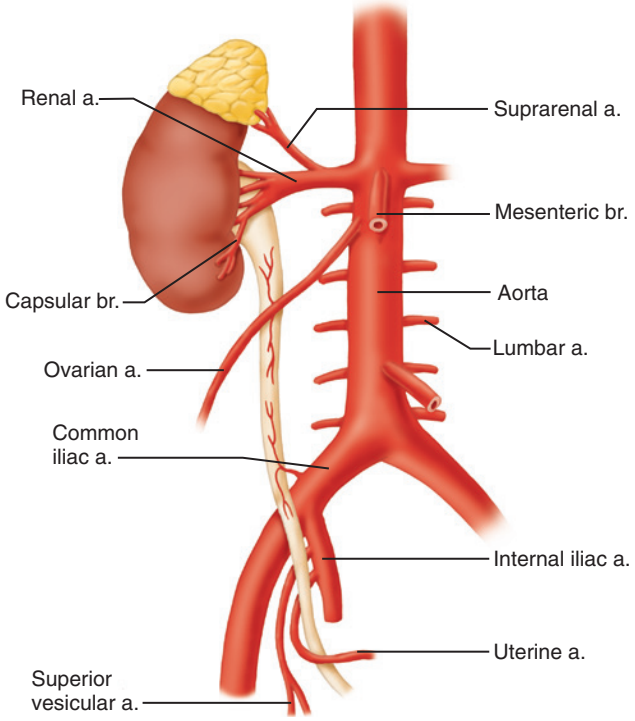


Figure 14.1 Blood supply to the ureter. Segmental blood supply to the ureter enters the proximal ureter medially and the pelvic ureter laterally. (With permission from Smith RB, Skinner DG (eds.). Complications of Urologic Disorders. Philadelphia: WB Saunders; 1976:131.)

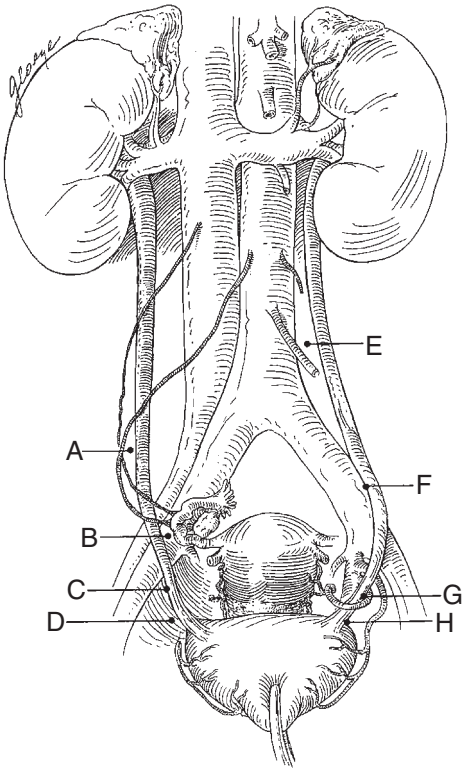


Figure 14.2 Common sites of ureteral injury. A, Division of the gonadal vessels and infundibulopelvic ligament. B, Resection of adnexal masses adherent to the ureter within the broad ligament. C, The apex of the obturator fossa in pelvic lymphadenectomy. D, Division of the lateral ligaments of the rectum in abdominoperineal resection. E, Division of the inferior mesenteric vessels in sigmoid resection. F, The pelvic brim during vascular bypass procedures. G, Division of the uterine artery during hysterectomy. H, The lateral vaginal fornix, entry into the trigone of the bladder during hysterectomy and vaginal procedures. (With permission from Payne CK, Raz S. Ureterovaginal and related fistuals. In: McAninch JW, ed. Traumatic and Reconstructive Urology. Philadelphia: WB Saunders; 1996:213.)

injure the ureter. Vascular grafts and repairs may injure the mid-ureter (Fig. 14.3).

Furthermore, several systemic illnesses may necessitate ureteral reconstruction. These include infection (tuberculosis, schistosomiasis), primary ureteral malignancy, ureteral fibroepithelial polyps (Fig. 14.4), and retroperitoneal or pelvic cancer with extrinsic invasion. Other benign diseases that affect the ureter include retroperitoneal fibrosis, inflammatory bowel disease, aortic and iliac aneurysms, ovarian vein entrapment, and pelvic lipomatosis.

External trauma to the ureter can be divided into blunt and penetrating trauma.[5] It is critical to note that ureteral injuries in these settings are frequently associated with concomitant injuries in other organ systems, so these also need to be explored.[6] For penetrating trauma (gunshot wounds), it is important to know the caliber of the weapon, as higher penetrating velocities have greater collateral damage. During emergent exploration, the ureter can appear normal, but over time tissue necrosis can result. Penetrating non-gunshot wounds such as knife wounds rarely have delayed tissue necrosis. It is important to visualize all sides of the potentially injured ureter. Blunt injuries may involve rapid deceleration, and the ureteropelvic junction is at risk for avulsion most commonly seen in children. Ureteral injuries associated with blunt and penetrating trauma are further reviewed in Chapter 15.

Diagnosis

The diagnosis of ureteral injury includes not only identifying the nature and extent of injury, but also assessment of the kidneys and bladder as a priority. It is important to know the overall renal function and account for the presence and condition of the contralateral kidney. The presence of bladder outlet obstruction, a small capacity bladder, and/or dysfunctional voiding may affect the outcome of the repair.

Intraoperative identification and direct inspection of the ureter allow for the characterization of the ureteral injury. Indigo carmine or methylene blue can be directly injected into the ureter or through a nephrostomy tube to determine if a leak is present. Retrograde pyelography can be performed to determine the area of extravasation, obstruction, or narrowing that would suggest a stricture. Intravenous pyelography can be performed in a trauma setting to evaluate the contralateral kidney. Tricks to identify the ureter intraoperatively include identification of the rhythmic peristalsis of the ureter with or without squeezing the ureter with forceps, movement of a previously placed yellow angiographic exchange catheter, or lighted ureteral catheters. The best method for identifying the ureter is to rely on anatomic knowledge. Two reliable areas are located anterior to the iliac bifurcation and lateral to the gonadal vessels at the level of the lower pole of the kidney.



Figure 14.3 Bilateral midureteral obstruction from vascular grafts. Intravenous pyelogram 90 minutes after contrast injection shows severe hydronureternephrosis to the level of the midureter.

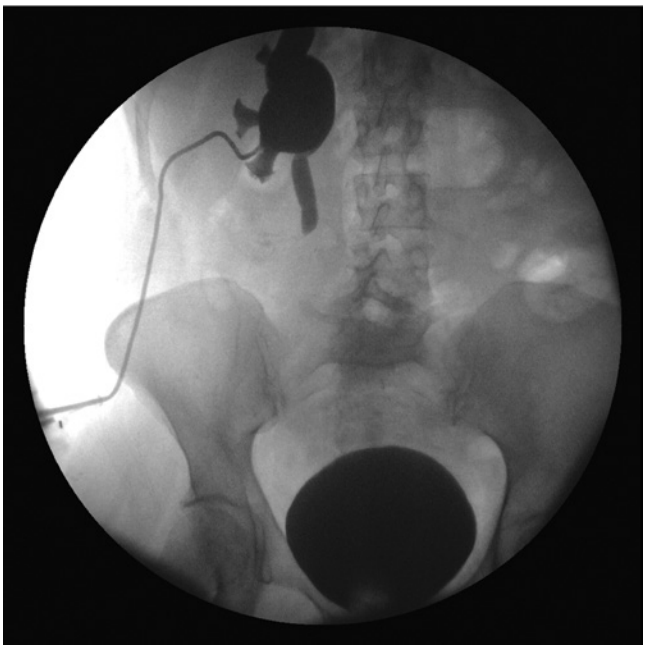


Figure 14.5 Antegrade nephroureterogram of a proximal ureteral injury. The flow of contrast abruptly stops at the level of the proximal ureter. A cystogram was also performed to determine bladder capacity.

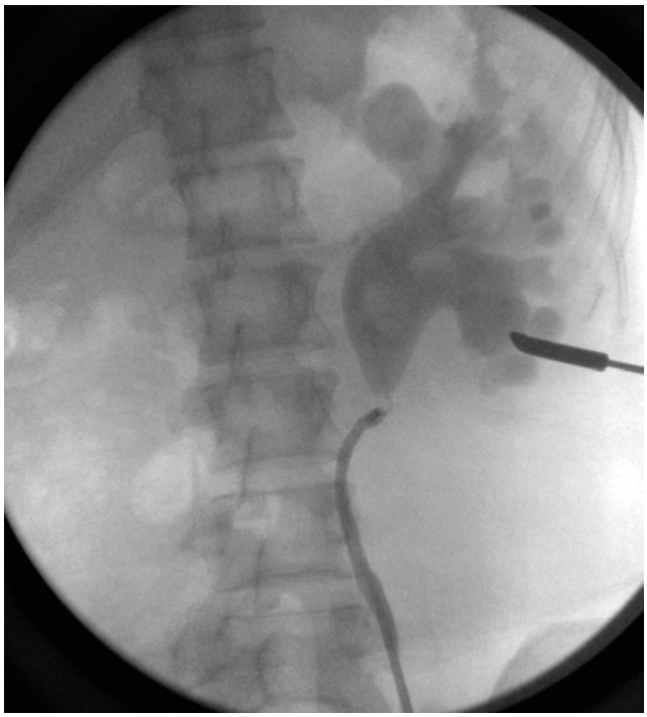


Figure 14.4 Fibroepithelial polyps causing obstruction at the ureteropelvic junction. Retrograde pyelography was performed showing the filling defect at the ureteropelvic junction. Visual confirmation of a fibroepithelial polyp was obtained with flexible ureteroscopy.

Most often, urologic imaging is best performed by the treating urologist, which allows for the assessment of the location and length of the injury. Retrograde imaging can delineate the status of distal ureteral pathology and evaluate the contralateral ureter. If a nephrostomy tube is present to protect renal function, antegrade imaging can be performed to delineate the extent of the proximal disease (Fig. 14.5). During cystoscopy, one can quantify capacity and compliance of the bladder and infer evidence of bladder outlet obstruction.

Anatomic imaging with computer tomography (CT) with delayed contrast imaging can be used to evaluate penetrating trauma with hematuria or any suspicion of genitourinary injury.[7] If nonenhanced contrast CT is performed, data are limited to the renal parenchymal thickness, status of the retroperitoneum and pelvis, and adjacent structures. MRI has the benefit of no ionizing radiation delivered and detection of hydronephrosis; however, it is a poor modality for stone detection and is limited in cases of low GFR (<40 mL/min) to administer gadolinium due to the risk of nephrogenic systemic fibrosis.[8] Delayed contrast imaging can provide information regarding the level of ureteral injury.

The length and location of the stricture is an initial marker for the type of repair feasible. Strictures >2 cm in length are unlikely to be resolved with endoscopic techniques. For segments ~2 cm, a ureteroureterostomy can be considered, with a centimeter on either side of the lesion needed to provide healthy tissue. For distal strictures or strictures of 4–5 cm, a ureteroneocystotomy can be performed. For 6- to 10-cm defects in the mid- to distal ureter, a psoas hitch can be considered. For 12- to 15-cm mid- to distal ureteral defects, a Boari bladder tube flap +/- combination with a psoas hitch can be considered. For repairs >15 cm or proximal defects, bowel interposition or autotransplant can be performed. Renal mobilization has been described to gain additional ureteral length; however, in our experience, mobilization of the kidney does not gain much length at the level of the proximal ureter.

Additional factors to consider for the affected kidney are the parenchymal thickness and the presence of incidental, asymptomatic hydronephrosis or symptomatic

hydronephrosis. It is important to have an understanding of the function of the contralateral kidney, presence of systemic diseases, and related infection or pyelonephritis if present, and to be able to rule out malignancy as a source of the obstruction.

Timing of Repair

A critical decision for surgeons is determining the optimal timing of repair relative to the timing of the injury. This decision is heavily influenced by how quickly the ureteral injury is recognized. In cases of delayed recognition, often local inflammation, urinary extravasation, intraabdominal adhesion of bowel distention, and/or the presence of infection may serve as obstacles to successful immediate repair. These factors contribute to failed repair owing to the condition and mobility of the tissues, and often delayed repair is warranted.

In the setting of an intraoperatively recognized ureteral injury, immediate repair is generally warranted in the absence of hemodynamic instability of medical compromise of the patient. In cases of ureteral laceration, debridement of devitalized tissue, followed by primary repair or selection of an appropriate reconstructive procedure is usually carried out. In cases of ureteral ligation, primary reimplantation, with or without ureteral interposition, is indicated. If the patient is unstable, then a temporizing maneuver to achieve proximal urinary drainage, with a plan to return at a delayed interval for definitive repair, is appropriate. In such cases, proximal drainage can be achieved by stent placement, or nephrostomy, depending upon the severity of the injury, and the patency of the distal ureter. In cases of ureteral transection, surgeons have often considered ureteral ligation with proximal nephrostomy drainage as a temporizing maneuver. It should be noted that devitalized ureters often break down leading to ureteral leakage or fistula, despite intraoperative ligation. Drainage of the ureteral injury site to ensure control of any delayed extravasation is wise.

When ureteral injury is not identified intraoperatively, but becomes evident 48–72 hours postoperatively, immediate repair can be considered, depending upon the mechanism of injury, severity of extravasation, and the medical condition and emotional state of the patient. Many patients are not mentally prepared for immediate return to the operating room or may be having difficulty with recovery. In these cases, temporizing maneuvers to relieve obstruction, drain extravasated urine, and achieve proximal diversion are very reasonable. In the case of a patient who is motivated for rapid resolution of the problem, has minimal to no urinoma collection, and is medically fit, early repair is an appropriate consideration. Beyond 72 hours, edema and local inflammatory reaction leading to friability of the tissue may lead to a lower likelihood of successful repair. In these cases, or in cases of more delayed recognition of the injury, immediate repair is not wise. Proximal drainage and control of any urinary fistula are warranted. Surgical repair may be delayed for 6–12 weeks to allow the injured region to scar in place and local inflammation to resolve completely. At the time of delayed repair, placement of an antegrade catheter to the point of the injury may aid in intraoperative identification of the injury.

Preoperative Management

Before repair is attempted, it is important to carefully document the location, length, and nature of the injury. It is important to define expectations and anticipate potential complications, and ask the questions, is the ureteral reconstruction likely to succeed or should a nephrectomy be performed? Can the reconstruction be performed in situ or does a backtable repair with autotransplant need to be considered to optimize success?

A ureteral injury worth repairing is dependent on the function of the ipsilateral and contralateral kidney and the age and overall health of the patient. The patient's cardiovascular status, anesthetic risk, and life expectancy should be considered. As a general rule, if the kidney can provide ~20% of the overall renal function, then it is worth saving. In other words, would the contralateral kidney support life if the kidney in question were removed? Relieving ureteral obstruction will rarely increase ipsilateral renal function; however, it will prevent further deterioration. Isotopic nuclear renography can provide information on renal split function if the kidney parenchyma appears marginal, and also the isotopic retention and excretory slope may indicate a patulous collecting system or presence of obstruction.

In the trauma setting, the primary goal is first achieving hemodynamic stability followed by identification of injuries.[7] There may be situations where a ureteral injury cannot be initially repaired due to hemodynamic instability or the poor or uncertain condition of the ureteral tissue. It may be necessary to ligate the ureter immediately proximal to the site of injury, place a nephrostomy tube, and return in a delayed setting for repair.

The timing of the repair should allow for optimization of nutrition and other systemic diseases, including diabetes mellitus, hypertension, and anticoagulation status. Drainage of the kidney can be temporized with a nephrostomy tube or a ureteral stent if continuity can be established. If definitive ureteral repair is planned but a ureteral stent is indwelling, the ease of the repair will be dramatically improved if the stent is removed at a minimum of 3–4 days prior to the procedure to allow for resolution of tissue edema. A sterile urine culture should be documented prior to reconstruction.

If the morbidity of reconstruction or nephrectomy outweighs the chance of success, permanent nephrostomy tube drainage or a chronic double J stent can be considered.[9] A downside of this approach is the discomfort related to these tubes and the need for frequent ureteral stent or nephrostomy tube changes to avoid encrustation. A metal Resonance stent[10] or tandem ureteral stents[11] can be considered as alternative options.

Strategies for the Management of Ureteral Injuries

Beyond an understanding of the anatomy, location, length, and type of ureteral injury, what is most important to approaching the management of ureteral injuries is an understanding of the nuances and limitations of each technique (Fig. 14.6). Here, we present technique-related tips

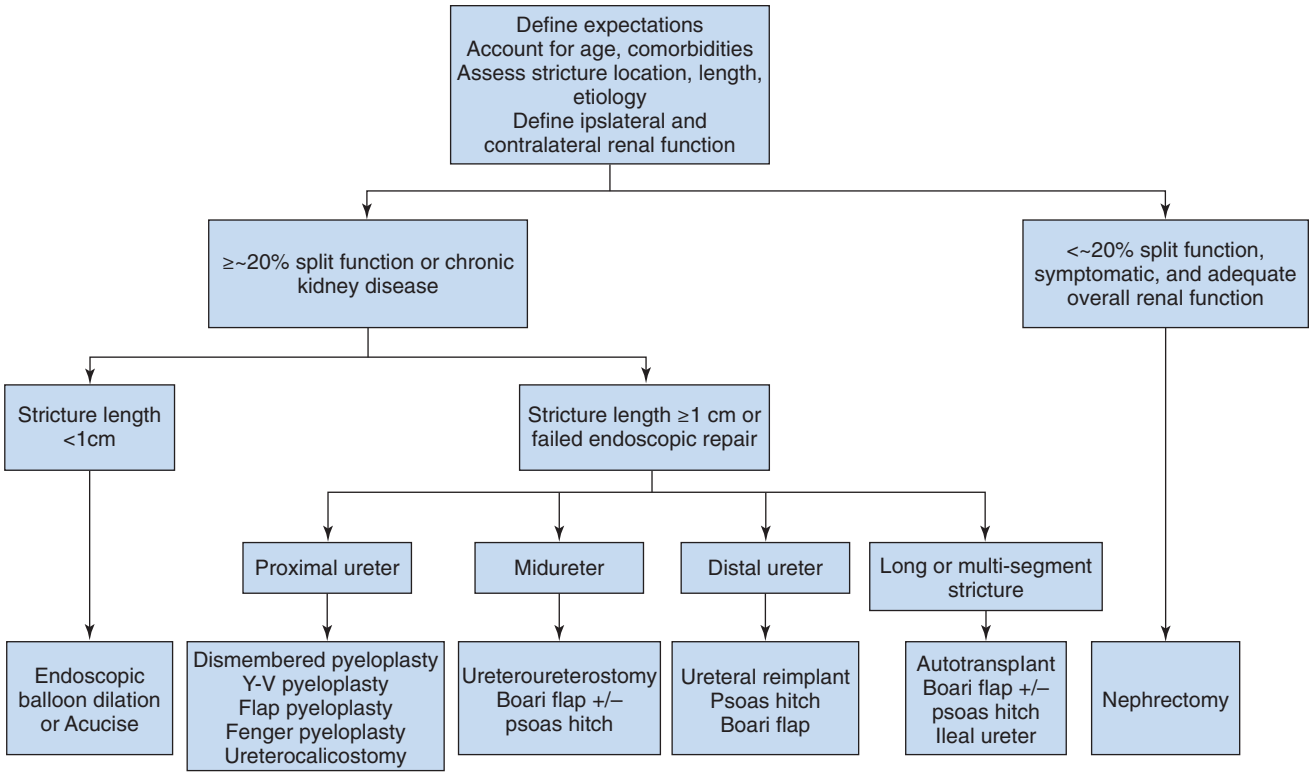


Figure 14.6 Workflow of ureteral injury management. The management strategy should incorporate the patient's expectations; age and comorbidities; stricture location and length and etiology; and overall and split renal function.

and tricks in the management of ureteral injury based on our experience. We separate the endoscopic approaches from the reconstructive techniques based on ureteral location. A complete guide to how to perform specific techniques or procedures can be found in several excellent atlases and references (*Hinman's Atlas of Urologic Surgery,*[12] *Glenn's Urologic Surgery,*[13] *Campbell's Urology*[14])[15] and will not be repeated here. Furthermore, whether the repair is performed using open, laparoscopic, or robotic-assisted approaches is less important than the approach with which the surgeon is most facile.[16]

The key principles of ureteral reconstruction include isolation of viable and healthy ureteral tissue, tension-free anastomosis, and intraluminal ureteral drainage with a ureteral stent for approximately 6 weeks. We generally perform refluxing repairs on all reconstructive cases because the goal is to minimize the risk of a future stricture, and usually there is a paucity of tissue to mobilize. We typically place a drain near the ureteral repair in the short term and a Foley catheter to prevent reflux and an overdistended bladder to facilitate drainage of the upper tracts.

ENDOSCOPIC REPAIR

The primary indication for endoscopic repair is for a short segment ureteral stricture. Endoscopic approaches can be divided into stricture incision or dilation.[17] The major advantage of these techniques over other reconstructive techniques is their minimal morbidity. Classically the ideal patient has a short, focal stricture ≤1 cm in length. For dense, longer strictures >1 cm in length, the rate of failure is high.

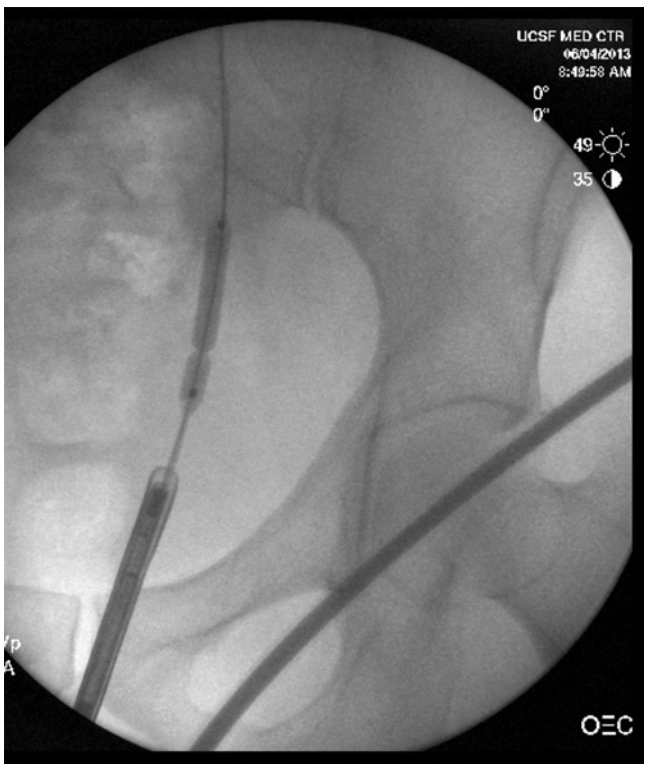


Figure 14.7 Balloon dilation of distal ureteral stricture. Note that the "waist" of the balloon indicates the location and caliber of the stricture. The goal of this technique is to have the "waist" disappear with sufficient pressure.

Balloon dilation of the stricture is relatively straightforward,[18] but several key points should be emphasized (Fig. 14.7). Retrograde pyelography should be obtained to fully identify the stricture, and the C-arm fluoroscopy unit should not be moved to ensure one can identify the stricture in relation to fixed boney landmarks. It is essential to pass the guidewire beyond the stricture. Initially a hydrophilic guidewire (straight or coude tipped – with or without a locking torque device) can help successfully pass the guidewire. It should be exchanged over an angiographic exchange catheter to place a nonhydrophilic guidewire to limit unintended dislodgement. In addition, ensure that that balloon profile is as tight as possible prior to back-loading it onto the wire so that it will most easily traverse the stricture. Inflate the balloon with contrast under fluoroscopy to ensure the balloon straddles the stricture.

Endoscopic stricture incision can be performed with a holmium laser[19,20] or the Acucise device[21,22] for endopyelotomy or endoureterotomy. The direction of the cut is critical to avoid injury to surrounding structures. If the stricture is proximal near the ureteropelvic junction, aim lateral. If the stricture is located near the iliac vessels, aim anterior. The holmium laser allows for more precision, as this is performed under direct vision. The laser should be passed beyond the stricture and cut as it is withdrawn. Laser settings should use a high frequency with low-power energy settings. The goal is to visualize the stricture "pop" open to allow visualization of fat, representing a transmural cut. The Acucise device can be deployed similarly, and, again, it is important to ensure that the balloon straddles the stricture. We typically initially fill the balloon with 1.0 mL and visualize the stricture under fluoroscopy and then cut for 5 seconds as one fills the balloon to a total of 2.2 mL. We recommend a 75-watt pure cut setting. If there is a concern whether the cut has occurred, after device removal there should be a characteristic cautery smell along the cutting wire. If the device needs to be reused, be aware that the profile of the balloon may be too large to successfully pass through the strictured segment. A nice trick is to use the writing on the Acucise port to guide the direction of the cut – if a lateral cut is desired, the writing should also be lateral. Finally, in our experience, we find that the cut is less effective if there is a high contrast concentration present. We therefore use dilute contrast during the initial retrograde pyelography. Finally, the 7/10Fr Acucise endopyelotomy stent can be placed for 4–6 weeks. It has no sideholes to prevent tissue ingrowth and narrowing of the lumen. Alternatively one can use a traditional 8–8.5Fr double J stent or a Schueller ureterotomy stent set manufactured by Bard (Covington, GA). This ureteral stent has an adjustable sleeve with a wider caliber that can be placed at the location of the stricture. It is widely used in Europe and is used less frequently in the United States.

As an aside, ureteral avulsion has been reported during ureteroscopy,[23,24] especially early in the adoption of the technique. In these cases, when this injury has been identified, it is best to stop the case, place a nephrostomy tube, and decide to come back at a later time to address the ureter. This is the time to regroup, talk to the patient and his or her family, and avoid a rash procedure (usually late at night). After the patient has been temporized with a nephrostomy tube, it is important to inform the patient what to expect from the different reconstruction options, and after a decision has been made on which repair to perform, it is important to assemble the right team to perform a definitive repair.

PROXIMAL URETERAL REPAIR

Ureteral reconstruction in the proximal ureter or ureteropelvic junction can often be challenging. The key to a successful outcome is achieving a tension-free anastomosis.[15] It has been described that renal mobilization can provide additional mobility of the proximal ureteral segment; however, in our experience, mobilization of the kidney does not gain much length. Additional factors that may complicate repair include surrounding hilar vessels, severe scarring, and a small intrarenal pelvis. Endoscopic endopyelotomy has been previously discussed, and it is best performed for short segment focal stricture ≤0.5 cm in length. Longer strictures can be treated; however, increasing stricture lengths have a higher failure rate in our experience.

A number of reconstructive techniques have been described for the ureteropelvic junction and proximal ureter, but one needs to be selective about which approach is best warranted dependent upon anatomy. These include the Foley Y-V pyeloplasty,[25] Anderson-Hynes dismembered pyeloplasty (Fig. 14.8),[26,27] Fenger pyeloplasty employing the Heineke–Mikulicz technique,[28] and use of different flaps created from a dilated, redundant renal pelvis. If a crossing vessel is present, a Hellstrom procedure can be considered, where the vessel is mobilized and displaced away (typically cephalad) from the area of obstruction using a hammock of surrounding fascia or fat.[29] For the dismembered techniques, it is critical that a wide spatulation is performed on both ends of the anastomosis to avoid stricture recurrence. We place interrupted, absorbable sutures to allow coaptation of tissue. In general, it is easiest to close the back wall of the anastomosis first, followed by ureteral stent placement, and then completion of the anterior wall.

Alternatively, if the renal pelvis is insufficient to perform a repair, one can perform a ureterocalicostomy.[30–32] Such decisions are typically anticipated with preoperative imaging. The prerequisite for this procedure is minimal parenchyma overlying the lower pole. The key to this procedure is to make a wide anastamosis to avoid stricture recurrence. Over the long term, however, a fundamental problem with these repairs is that they often do not drain well, as there is the propensity of urine from the lower pole to propel toward the renal pelvis due to physiologic peristalsis, rather than through a wide-open anastomosis. This may result in subsequent stones, infections, and pain. These are often very complicated cases with the repairs being the option of last resort.

Ureteral stent placement during these cases can sometimes be tricky, especially during laparoscopic or robotic-assisted cases. We recommend having a 3-way Foley catheter in place at the start of the case. The bladder can be filled to ~200 mL (with or without methylene blue), so that when a wire is placed antegrade, it will easily coil in the bladder. This will ensure a reliable distal stent curl. The methylene blue may be seen refluxing after appropriate placement into the bladder. A pre-soaked wire in mineral oil will facilitate the passage of the stent. One can use ultrasound or a flexible cystoscope to ensure accurate placement.

Frequently these cases have concomitant stone disease. It is better to address these at the time of reconstruction

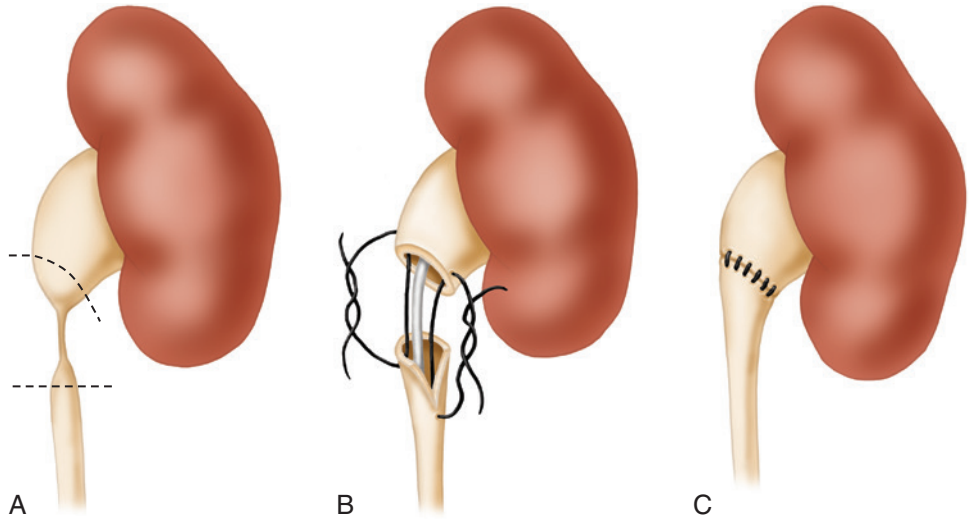


Figure 14.8 Dismembered pyeloplasty. A, Dotted lines denote area of diseased ureter and planned incision. B, After excision of the diseased segment, the proximal ureter is spatulated. We find it easiest to place full-thickness, interrupted absorbable sutures along the back wall first, followed by antegrade ureteral stent placement, then completion of the anastomosis of the anterior wall. C, After completion of the anastomosis, we prefer to leave the stent in place for 6 weeks and the Foley catheter for 1 week. (With permission from Wein AJ, Kavoussi LR, Campbell MF. Campbell-Walsh Urology, 10th ed. Philadelphia, PA: Elsevier Saunders, 2012: Figure 41.16.)

rather than later. The extraction of stones can be performed using a flexible cystoscope or ureteroscope through a laparoscopic port.[33,34] Often these cases can be frustrating due to the additional equipment required and the irrigation fluid flowing into the operative field.

MIDURETERAL REPAIR

Midureteral repairs are challenging because they are located near the iliac vessels and it is difficult to gain mobility of the ureter proximally or distally. These are often the most difficult reconstructive cases to perform. For short segment strictures of 2 cm or less a ureteroureterostomy can be performed (Fig. 14.9).[35–37] After transection of the ureter is performed at the level of the stricture, we perform a wide spatulation and place interrupted, absorbable sutures to allow tissue coaptation. It is easiest to close the back wall of the anastomosis first, followed by ureteral stent placement, and then completion of the anterior wall. If omentum is available, this can add additional backing to the repair.

Additionally, other approaches can be considered, but caution should be exercised as to the limitations of each technique. For right-sided repairs, it is tempting to use the appendix or the fallopian tube because of a good native blood supply. However, in our experience these all uniformly fail in the long term. On the left side the ureter can be anastomosed directly into the sigmoid or descending colon. There is a known neoplastic potential in these cases;[38] however, these are typically desperate situations when they are performed. In addition, buccal graft ureteroplasty recently has been described, although with limited follow-up.[39–42] Different approaches have been described, including using the ureteral adventitia as a backing or using perirenal or omental fat behind an augmented graft. Additional follow-up is needed to determine the durability of such repairs.

Often creativity can provide a successful outcome for these especially difficult repairs. If there is a nonfunctioning kidney on the contralateral side, a nephrectomy can be performed on that kidney, and end-to-end ureteroureterostomy can be performed.[43,44] The contralateral ureter can be mobilized and anastamosed to the proximal ureter on the ipsilateral side. The kidney would then drain to the contralateral trigone. In these rare cases, it is critical to know the overall renal function and relative function of each kidney. If there are bilateral strictures, we have performed a "reverse 7" procedure using a segment of small bowel. Maintaining an isoperistalic orientation, the proximal end of the bowel is delivered through a window in the mesentery. The proximal end is anastamosed to the ureter or renal pelvis on each side (typically required through a mesenteric window), and then the distal end is connected to the dome of the bladder. As in other cases where bowel segments are placed in the urinary tract, there should be adequate renal function (serum creatinine >2 mg/dL) and absence of inflammatory bowel disease or radiation enteritis. Postoperative issues include the risk of urinary tract stones, infection, and electrolyte imbalance.

Finally, a psoas hitch (Fig. 14.10) combined with a Boari flap pyelovesicostomy is an option for high midureteral strictures or longer segment strictures.[45,46] In these cases both separate or combined, it is critical to ensure an adequate starting bladder capacity of at least 300 mL, as these procedures will invariably diminish the size of the bladder. If there is a small capacity bladder, then another reconstructive approach should be considered. For both procedures, a key step is mobilization of the contralateral bladder from the peritoneal attachments. We typically do not divide the contralateral pedicle, as this is often unnecessary.

With the psoas hitch procedure alone, it is usually possible to elevate the bladder to a level above the iliac vessels (Fig. 14.10).[47,48] Prior to creating the oblique anterior cystotomy, we distend the bladder with irrigant to get a sense of how much length the psoas hitch alone will provide. When placing the nonabsorbable sutures into the psoas muscle, it is important that the direction of the sutures is longitudinal, not transverse, to avoid entrapment of the genitofemoral or femoral nerves.

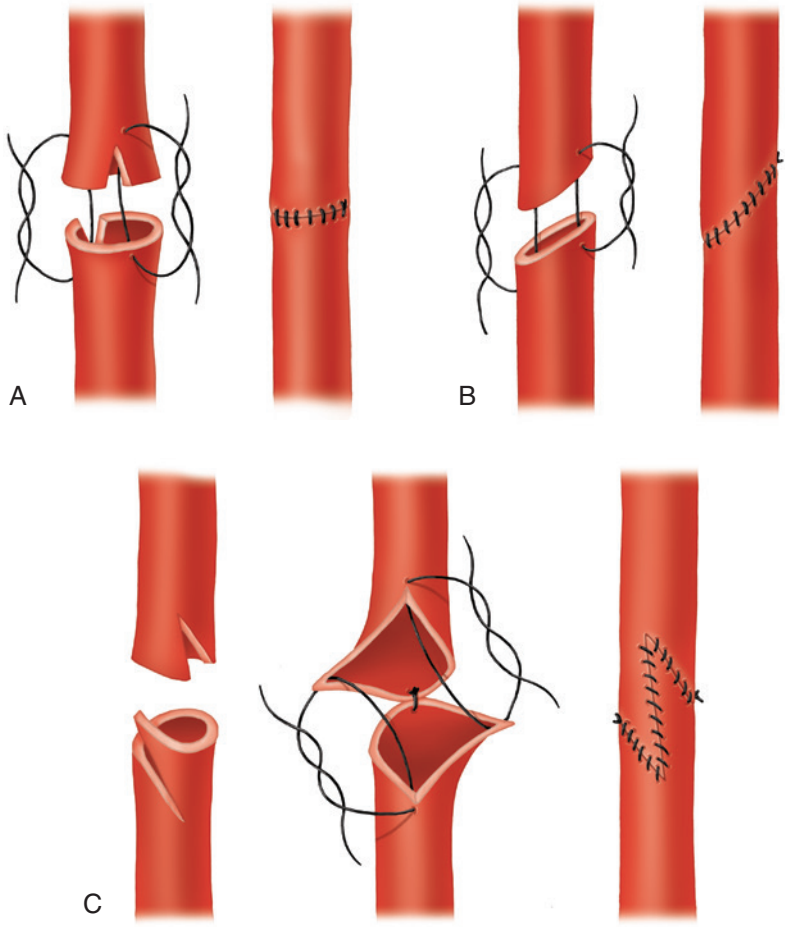


Figure 14.9 Ureteroureterostomy techniques to maximize luminal diameter. A, Spatulation of ureteral margins. B, Oblique anastomosis. C, Z-plasty technique. (With permission from Smith RB, Skinner DG (eds.). Complications of Urologic Disorders. Philadelphia: WB Saunders; 1976:137.)

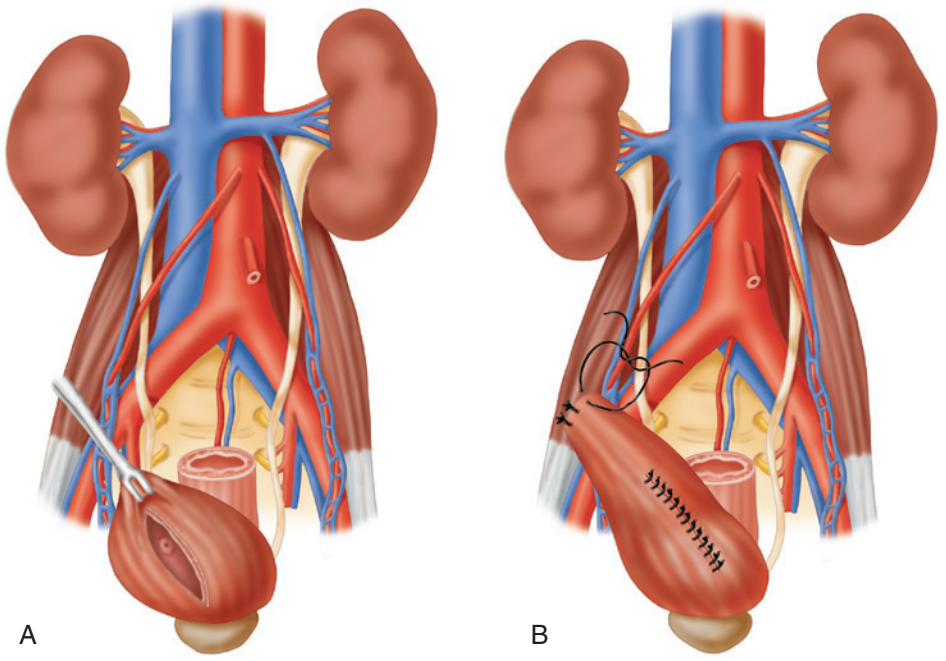


Figure 14.10 Psoas hitch. A, An anterior cystotomy is performed following bladder mobilization. We typically do not divide the contralateral bladder pedicle. B, The bladder dome is fixed to the ipsilateral psoas tendon, and the ureteral reimplantation is completed. (With permission from Wein AJ, Kavoussi LR, Campbell MF. Campbell-Walsh Urology. 10th ed. Philadelphia, PA: Elsevier Saunders, 2012: Figure 41.31.)

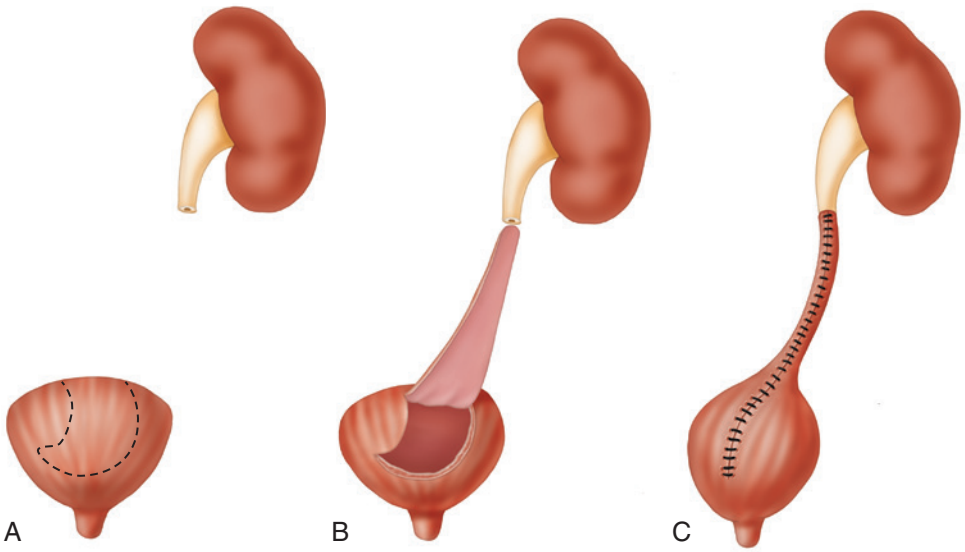


Figure 14.11 Boari flap. A, The intended flap is marked on the mobilized bladder. B, The flap is created with the base ~4 cm in width, and the flap length not exceeding three times the width of the flap. C, Completion of the flap. (With permission from Wein AJ, Kavoussi LR, Campbell MF. Campbell-Walsh Urology. 10th ed. Philadelphia, PA: Elsevier Saunders, 2012: Figure 41.33.)

The key to a successful Boari flap is being aware of the vascular supply in relation to the flap length (Fig. 14.11).[49–51] Typically, the base of the flap should be ~4 cm in width, and the flap length should not be more than three times the width of the flap. It is important to avoid an hourglass deformity by creating a wider base with a slow taper toward the tip of the flap.

DISTAL URETERAL REPAIR

Distal ureteral repairs can be deceptively challenging because after crossing the iliac vessels, the course of the ureter dives into the deep pelvis, and it is often difficult to identify the ureter and surrounding structures. In our experience, we feel it is important to inform male patients that there is risk of injury to the vas deferens during these repairs. Often there is significant scarring in these cases, and ligation of the vas is needed to expose and mobilize the distal ureter.

The main options for distal ureteral repair include direct reimplant into the dome of the bladder[37,52,53] or a psoas hitch.[47,48] The selection of which procedure to perform depends on the location and length of the stricture and the bladder capacity of the patient. Distally located and short-segment strictures are best addressed with a reimplantation. More proximally located and longer strictures may require a psoas hitch or a combined psoas hitch with a Boari flap.

LONG-LENGTH URETERAL REPAIR

There are few options for treating long-length or multisegment ureteral strictures. The main options include a psoas hitch combined with a Boari flap, ileal ureter, and autotransplant. As mentioned before, a contralateral nephrectomy with a transureteroureterostomy can be performed if the contralateral kidney has minimal function. While others have reported good outcomes,[45,54–57] it is our preference that we avoid performing ileal ureters, primarily because we have now added a second organ system to the picture.[58] Furthermore, there are metabolic consequences of interposed bowel segments,[59] in addition to the risk of stone formation, mucus production, and urinary tract infection. These cases should be restricted to patients with adequate bladder capacity and renal function (GFR >30 mL/min) who have no inflammatory bowel disease or radiation enteritis.

More recently, we have been doing more laparoscopic nephrectomy followed by autotransplant procedures for the most difficult strictures.[60] This is a last-ditch effort where there is a tremendous amount of scar tissue. The advantage of this procedure is that it allows for reconstruction of the ureter and renal pelvis under cold ischemia on the back table, which is much easier than with an open or minimally invasive approach. The key is to identify the proximal point at which there is no scarring. Depending on the degree of scarring of the ipsilateral iliac fossa, sometimes we need to place the kidney on the contralateral side. If the extent of the stricture is very proximal, a pyelovesicostomy can be performed on the transplanted kidney.[61] It is important to develop a good relationship with the transplant team and perform these procedures as a team effort to optimize success.

OTHER CONSIDERATIONS

Often anatomic kidney variants can add further complexity to ureteral reconstruction. For pelvic kidneys, we often perform a pyelovesicostomy due to the proximity of the kidney to the bladder.[62] For horseshoe kidneys it is important to be aware of the location of the multiple hilar vessels that are often present. The ureters travel anterior to the isthmus of the kidney, which is located below the inferior mesenteric artery. It has been reported that transecting the

isthmus along an avascular plane can facilitate reconstruction. However, each of these unique cases requires specific attention to each situation.[63]

Summary

Ureteral injuries are frequently multifactorial in etiology, and successful management requires an intimate knowledge of the anatomy and the available tools for repair. The goal of repair is to restore quality of life and preserve renal function, while minimizing morbidity. Often this requires more than one procedure over the course of weeks to months. The best-equipped surgeon is not only a creative surgeon who understands the advantages and limitations of each technique, but also one who can communicate and connect with the patient and his or her family to determine the optimal repair.

References

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Chapter 14 Questions

1. Two good areas to identify the ureter include:
   a. At the crossing of the gonadal vessels and insertion into the bladder
   b. At the hilum and lateral to the gonadal vessels at the level of the lower pole of the kidney
   c. At the iliac bifurcation and crossing of the vas deferens
   d. At the iliac bifurcation and lateral to the gonadal vessels at the level of the lower pole of the kidney
   e. At the level of the lower pole of the kidney lateral to the gonadal vessels and crossing of the vas deferens

2. The length and location of a ureteral injury can be determined by:
   a. Retrograde ureterography
   b. CT scan
   c. MRI
   d. MAG3 renogram
   e. Ultrasound

3. A 73-year-old male presents with a symptomatic 3-cm distal ureteral stricture secondary to multiple stone procedures. Serum creatinine is 1.2 mg/dL. CT imaging shows left-sided hydronephrosis and thinned parenchyma. Renogram shows 18% split function on the left and 82% on the right. What is the next step?
   a. Endoscopic balloon dilation
   b. Nephrectomy
   c. Ureteral reimplant
   d. Ureteral stent
   e. Observation

4. During exploratory laparotomy for penetrating gunshot wounds, it is noted that there is a right midureteral injury. While the ureter is being inspected for repair, the patient becomes unstable. What is the next step?
   a. Ligate the ureter proximal to the site of injury and plan a postoperative nephrostomy tube
   b. Complete the ureteroureterostomy
   c. Place a ureteral stent
   d. Perform an intraoperative intravenous pyelogram
   e. Nephrectomy

5. A 46-year-old female presents with a failed ureteropelvic junction (UPJ) repair with a 1-cm stricture 1 year postoperatively. An endopyelotomy is planned. The thickness and direction of the cut should be:
   a. Intraluminal and lateral
   b. Transmural and lateral
   c. Intraluminal and medial
   d. Transmural and medial
   e. Transmural and superior

6. For a Boari flap repair of a midureteral stricture, the ratio of the length of the flap to the base should be not more than:
   a. 1:1
   b. 2:1
   c. 3:1
   d. 4:1
   e. 5:1

7. A 64-year-old female with Crohn's disease and a long history of stone disease presents with a symptomatic left 1-cm proximal ureteral stricture and a 3-cm distal ureteral stricture. Serum creatinine is 1.5. Split function of the left kidney is 41%. What is the next step?
   a. Autotransplantation
   b. Ileal ureter
   c. Combined UPJ repair and ureteral reimplant
   d. Boari flap with renal mobilization
   e. Nephrectomy

8. In a horseshoe kidney where is the the UPJ located?
   a. Medial to the inferior calyx
   b. Lateral to the inferior calyx
   c. Over the isthmus
   d. Posterior to the renal parenchyma
   e. Lateral to the superior calyx

9. The blood supply of the ureter arises from:
   a. Segmental sources medially, proximally, and laterally in the pelvic ureter
   b. Segmental sources laterally, proximally, and medially in the pelvic ureter
   c. Segmental sources laterally
   d. Segmental sources medially
   e. Segmental sources anteriorly and medially

10. The smooth muscle of the ureter is thinnest at:
    a. UPJ
    b. Proximal ureter
    c. Midureter
    d. Over the iliac vessels
    e. Ureterovesical junction

Case Study

You are managing a 68-year-old male has a history of Crohn's disease, long history of urinary stone disease and multiple stone surgeries. He is referred to your office after a recent surveillance ultrasound showed a large left renal stone and sided moderate hydroureteronephrosis. He has a history of brachytherapy for prostate cancer and PSA has remained stable. He has left sided flank pain. He has moderate urinary symptoms and denies any gross hematuria. He is otherwise healthy. Serum creatinine is 1.9 mg/dL.

1. What diagnostic imaging workup would you recommend as the next step?
   a. Noncontrast CT abdomen and pelvis
   b. Repeat renal ultrasound
   c. Lasix renogram
   d. Retrograde pyelogram
   e. CT abdomen and pelvis with and without contrast (urogram)

The CT shows no ureteral stones, but there is a 2cm nonobstructing renal stone. The moderate hydroureteronephrosis extends down to the left distal ureter, where the caliber abruptly narrows near the ureterovesical junction. The parenchyma of the right kidney appears thicker than the kidney on the left.

2. What is the next course of action for your patient?
   a. Lasix renogram
   b. Cystsocopy and retrograde pyelogram and possible ureteral stent placement
   c. Percutaneous nephrolithotomy
   d. Bone scan
   e. Antegrade ureteroscopy

Retrograde pyeloureterogram shows a left sided distal ureteral stricture. His risk factors for stricture development include brachytherapy and multiple stones surgeries. A wire is unable to access beyond the stricture. Retrograde ureteroscopy shows a blind-ending lumen. No bladder lesions or tumors are seen. The patient undergoes a nephrostomy tube placement. His flank pain resolves but he has pain from the nephrostomy tube.

3. What is the next best step to determine the length of the stricture?
   a. Lasix renogram
   b. CT pelvis with and without contrast
   c. MRI pelvis with and without contrast
   d. Antegrade nephrostogram
   e. Cystogram

The stricture length is 3 cm and the cephalad border is at the position of the iliac vessels.

4. To help determine his options for reconstruction, what diagnostic study is indicated next?
   a. MAG3 lasix renogram
   b. PET CT
   c. DMSA renogram
   d. CT abdomen and pelvis with and without contrast (urogram)
   e. Cystogram

5. If his split renal function on the left is 8%, what is the next best step?
   a. Ureteral reimplant and possible psoas hitch
   b. Ureteral reimplant and possible Boari flap
   c. Ileal ureter
   d. Renal autotransplantation
   e. Nephrectomy

6. If his split renal function on the left is 40%, and he strongly wishes to maintain renal function (keep his left kidney). What is the next best step?
   a. Evaluate bladder capacity
   b. Ureteral reimplant and possible psoas hitch
   c. Ureteral reimplant and possible Boari flap
   d. Ileal ureter
   e. Renal autotransplantation

A cystogram is performed and his bladder capacity is 250mL.

7. What is the best reconstruction option for the patient?
   a. Ureteral reimplant and possible psoas hitch
   b. Ureteral reimplant and possible Boari flap
   c. Ileal ureter
   d. Renal autotransplantation
   e. Transuretero-ureterostomy

Answers

1. **d.** The iliac bifurcation and lateral to the gonadal vessels at the level of the lower pole of the kidney are two areas that are most easily identified intraoperatively.
2. **a.** In contrast to the other diagnostic studies listed, retrograde ureterography allows for the identification of the length and location of a ureteral injury.
3. **b.** Nephrectomy is the best choice due to the presence of a minimally functioning left kidney and symptoms.
4. **a.** Because the patient is hemodynamically unstable, it is best to temporize the injury. After the patient is stabilized, a repair can be planned in the elective setting.
5. **b.** The depth of the cut should be transmural, and the direction of cut should be away from hilar/vascular structures.
6. **c.** The Boari flap length should not be more than 3 times the width of the flap to avoid ischemia of the anastomosis.
7. **a.** Autotransplantation is the best answer because of the need to preserve renal function (presence of renal sufficiency), presence of bowel disease (avoid ileal ureter), and having a multifocal and long-length stricture.
8. **a.** In a horseshoe kidney, the inferior calyx is located inferior and medial to the UPJ. The proximal ureter travels anterior to the isthmus of the kidney.
9. **a.** The blood supply of the ureter is segmental and arises from medially proximally and laterally in the pelvic ureter.
10. **b.** The smooth muscle of the ureter is thinnest at the UPJ, which makes this area particularly susceptible to injury.

CASE STUDY

1. **a.** A noncontrast CT abdomen and pelvis is indicated to determine if an obstructing ureteral stone is present, given his history, and the extent of the hydroureteronephrosis. It is also helpful to elucidate the parenchymal thickness of his kidneys as a surrogate for split renal function.
2. **b.** The next step needed is to determine the etiology of the hydroureteronephrosis, including the location and length of a potential stricture. This is likely the cause of his symptoms. The stone is non-obstructing and does not need to be addressed immediately.
3. **d.** Antegrade nephrostogram will delineate the cephalad extent of the stricture, and combined with the retrograde ureterogram, a length can be determined.
4. **c.** It is important to evaluate the split function of his left kidney compared to the right kidney to determine if nephrectomy versus reconstruction is indicated. A Lasix washout study is not needed because it is already known he is obstructed.
5. **e.** Given his kidney is minimally functional on the left, his best option is nephrectomy.
6. **a.** He has moderate urinary symptoms and history of brachytherapy. Because the stricture is located in the distal ureter, it would be indicated to determine his bladder capacity prior to reconstruction. If his bladder

capacity were very limited, performing a psoas hitch or Boari flap would be difficult and may worsen his urinary symptoms.

7. **d.** He would likely require a Boari flap to reach the anastomosis, however patient has a limited bladder capacity. Mobilization of the bladder will be also difficult given his history of brachytherapy. His history of Crohn's disease and borderline renal insufficiency makes him not a good candidate for an ileal ureter. Autotransplantation is the best option given the lack of remaining options and would allow for pyelolithotomy to address his renal stone during cold ischemia.

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15 Management of Complications Related to Traumatic Injuries

ALLEN MOREY and TIMOTHY TAUSCH

CHAPTER OUTLINE

Renal Trauma
- Etiology and Management
- Complications

Ureteral Trauma
- Etiology and Management
- Complications

Bladder Trauma
- Etiology and Management
- Complications

Urethral Trauma

Posterior Urethral Injuries
- Diagnosis
- Management
- Complications

Anterior Urethral Injuries
- Diagnosis
- Management
- Complications

External Genitalia

Penile Fractures
- Etiology and Management
- Complications

Penile Amputation
- Etiology and Management
- Complications

Testicular Trauma
- Diagnosis and Management
- Complications

Chapter 15 Questions and Answers

KEY POINTS

1. With enhanced diagnostic accuracy in modern imaging techniques, hemodynamically stable renal trauma patients should be managed with non-invasive treatment, reserving either endovascular or surgical intervention only if unstable.
2. Intraperitoneal and complicated extraperitoneal bladder ruptures should be managed operatively, and uncomplicated extraperitoneal injuries with urethral drainage.
3. In pelvic trauma patients, indicative symptoms (blood at the meatus, inability to urinate, palpable bladder), or the inability to pass a urethral catheter, should prompt evaluation for a urethral injury with a retrograde urethrogram.
4. Management of posterior urethral disruption injuries due to pelvic trauma includes immediate bladder decompression with a suprapubic catheter, followed by either primary endoscopic realignment or a delayed elective urethroplasty.
5. Patients with a classic history suggestive of penile fracture should undergo immediate surgical repair, while imaging (ultrasound or magnetic resonance imaging) may aid in diagnosis in unclear cases.

Renal Trauma

Management of renal injuries has evolved significantly over the preceding decades, concomitant with advances in validated organ injury scaling systems and minimally invasive angiographic interventions. Whereas nephrectomy was common and the traditional standard of care, the vast majority of both blunt and penetrating injuries can now be managed nonoperatively.

Etiology and Management

Injury to the kidneys is the most common genitourinary trauma encountered, accounting for 24% of traumatic abdominal solid organ injuries.[1] Due to their retroperitoneal location, the kidneys are fixed only by the renal pelvis and vasculature, rendering them susceptible to deceleration injuries. Contrast-enhanced computed tomography (CT) scanning, with delayed images, remains the most common method for evaluating both vascular and collecting system trauma.

Although operative exploration was the traditional method of treatment, the paradigm has shifted to nonoperative management. Emergent surgery often results in nephrectomy,[2] and with advances in imaging, monitoring, and endovascular techniques, most injured kidneys can now be effectively preserved.[3] The current American Urological Association guidelines on urotrauma now advocate

for noninvasive management of any patient with a renal injury who is hemodynamically stable, and compulsory intervention (either endovascular or surgical) in unstable patients with poor response to resuscitation.[4]

Complications

A common problem following renal trauma is persistent urinary extravasation, which can result in urinoma, perinephric infection, or even renal loss. Systemic antibiotics and close observation result in resolution in many patients.[5] In patients with a persistent urine leak on repeat imaging (48 hours later), or with complications such as enlarging urinoma, fever, pain, ileus, fistula, or infection, urinary drainage with an internalized ureteral stent should be performed.[4] Drainage helps to avoid further complications, such as perinephric abscess.

Occasionally, patients may present with a delayed hemorrhage several weeks following the initial trauma, and the immediate treatment is bed rest and hydration. If the bleeding persists, then endovascular arteriography can usually localize the vessel, which can then be controlled with embolization. Rarely hypertension can be encountered, resulting from stimulation of the renin-angiotensin axis from renal ischemia due to renal artery stenosis (Goldblatt kidney), compression of the parenchyma by hematoma or urinoma (Page kidney), or arteriovenous fistula.[6,7]

Ureteral Trauma

Traumatic injuries to the ureter are rare, comprising only 1% of urologic trauma. Although external and endoscopic trauma can injure the ureter, a common cause is iatrogenic injury, occurring in gynecologic, urologic, or colorectal surgical cases.[8] The management of iatrogenic ureteral injury is discussed in detail in Chapter 14, and reconstructive procedures are discussed in Chapter 43. As injuries of the ureter associated with trauma are typically penetrating in nature, treatment with either placement of a ureteral stent or surgical repair depends on the location and severity of the injury.

Etiology and Management

Because of its anatomic location in the retroperitoneum protected by the vertebrae and musculature, the ureter is less susceptible to traumatic forces. For this reason, ureteral injury is present in less than 4% of all penetrating and less than 1% of all blunt trauma cases.[9]

In cases where ureteral injury is suspected, intravenous contrast-enhanced axial imaging with delayed films is recommended, or direct visualization during laparotomy if no preoperative imaging is available. In stable patients, lacerations can be primarily repaired, and contusions can be stented or resected and repaired, depending on the nature and severity of the injury. Either a stent or percutaneous nephrostomy (if a stent cannot be placed) can divert the urine from a partial or delayed presentation of a ureteral injury, with a definitive repair at a later date when the patient has recovered from the acute trauma.[4]

Complications

If unrecognized, significant complications can arise, making a prompt, accurate diagnosis imperative in managing these patients. A missed and persistent ureteral urine leak can lead to urinoma formation (Fig. 15.1), abscess, ureteral stricture, fistula, and potentially the loss of an entire ipsilateral kidney. Patients with missed ureteral injuries can suffer increased nephrectomy rates and prolonged hospital stays.[10]

Bladder Trauma

Etiology and Management

As the bladder is anatomically located deep in the bony pelvis, it is relatively protected from external traumatic forces. Significant blunt forces, such as rapid decelerations, falls, or crushes, can rupture the bladder, as well as penetrating injuries such as bone shards, projectiles, or surgical iatrogeny. Because of the forces necessary to compromise the bladder inside of the bony pelvis, concomitant injuries are common (80–94%), and mortality rates can be high, usually from nonurologic causes.[11–13]

Diagnosis can be made when clinically suspected, such as when conscious patients have suprapubic or abdominal pain and inability to void following the inciting event. Associated injuries or altered mental status can mask the symptoms; therefore when the mechanism suggests a potential bladder injury, evaluation should be undertaken. Gross hematuria upon catheter placement is typically the first indication and is nearly universally present.[14,15] Difficult catheter placement or blood at the meatus can indicate a concomitant urethral injury, and a retrograde urethrogram should be performed in these cases.

Bladder ruptures are best evaluated with a cystogram with drainage films. Alternatively, axial imaging with contrast instilled in the bladder can be utilized in stable patients. In uncomplicated patients, extraperitoneal bladder ruptures should be managed conservatively with urethral drainage alone, typically for 14 days following injury, which can be removed when a cystogram confirms no leak of contrast. If a patient is complex, with other injuries that necessitate laparotomy or orthopedic intervention, once stable the patient should undergo immediate repair of extraperitoneal injuries, as complications rates are lower.[16,17]

Intraperitoneal ruptures should be managed by immediate operative repair, as these injuries are unlikely to heal with conservative management and are often more severe than suggested in imaging studies. Careful inspection of the ureters and evaluation for clear efflux can evaluate for ureteral injury, with repair or stenting as indicated. A urethral catheter is again left and bladder integrity confirmed via cystogram prior to removal to ensure proper healing.

Complications

When promptly diagnosed and appropriately managed, complications following bladder injuries are minimized. Delayed or missed diagnoses can result in significant morbidity, as in patients with devastating complex pelvic trauma. If missed, patients can develop acidosis, azotemia, infection with fever and sepsis, acute renal failure, peritoneal signs, ileus, urine ascites, and even respiratory compromise from abdominal compartment syndrome. In complex genitourinary or concomitant colorectal injuries,

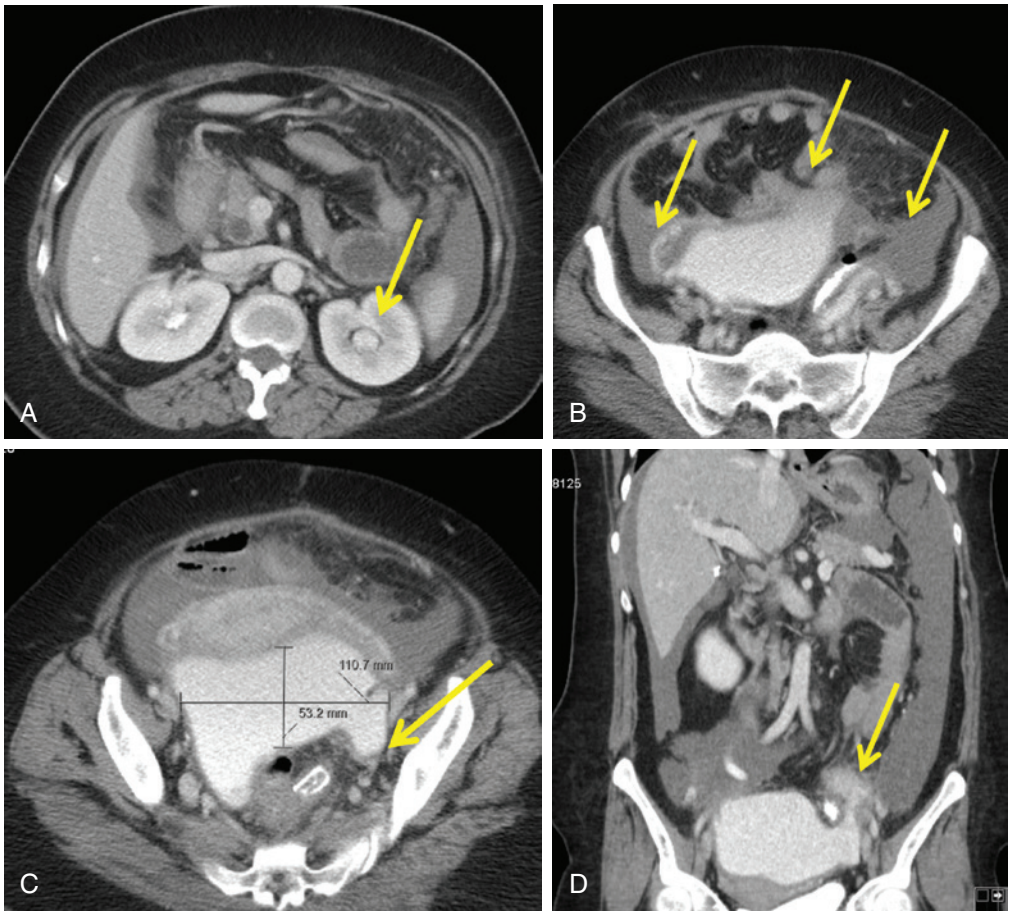


Figure 15.1 Delayed recognition of a ureteral injury following colon surgery. The patient presented with fevers and concern of pelvic abcess. A CT urogram demonstrates (A) proximal left hydronephrosis (arrow), (B) urinary ascites with layering contrast within ascites fluid (arrows), (C) extravasation into the urinoma from the site of ureteral injury (arrow), and (D) a phlegmon surrounding the uteral extravasation (arrow). (Figure provided by Samir Taneja.)

incontinence, fistulas, or strictures can develop, necessitating difficult and complex reconstructive surgery.

Urethral Trauma

Prompt recognition and diagnosis of urethral injuries are critical to successful management to optimize outcomes and prevent delayed complications. The location of the stenosis guides management, with specific mechanisms of injury to either the anterior (pendulous and bulbar) or posterior (membranous and prostatic) urethra influencing therapies. Acute management of any urethral trauma typically involves diverting urine away from the injury, and while many anterior urethral defects are amenable to immediate surgical management, many patients with posterior injuries ultimately require formal surgical repair several months later.

POSTERIOR URETHRAL INJURIES

Injuries of the posterior urethra are typically "disruption" type injuries, usually occurring in conjunction with multisystem trauma such as motor vehicle accidents, falls, or industrial accidents. These injuries are almost always encountered in conjunction with fracture of the anterior pelvic ring or pubic diastasis, with the degree of displacement correlated to a higher risk of urethral injury.[18] Conversely, only 10–15% of pelvic fractures are associated with urethral injury. Bladder injury has also been diagnosed in 10–20% of patients with pelvic fracture and urethral injury.[19]

The clinical and surgical appearance of each form of posterior urethral injury may differ. Endoscopic or open prostate surgery is associated with continuity strictures and preservation of the distal external urinary sphincter. In contrast, pelvic fractures are associated with urethral disruptions of the membranous urethra. These injuries have been termed "pelvic fracture urethral injuries" (PFUIs). Interestingly, a report has found that 7 of 10 patients examined at autopsy had urethral disruption after pelvic fracture *distal* to the external urinary sphincter, disputing the historical view that these injuries occur at the interface of the fixed prostatic apex and the less supported membranous urethra.[20] Additionally, urodynamic studies have demonstrated a functional rhabdosphincter at the prostatomembranous region in many patients after anastomotic posterior urethroplasty for PFUI.[21]

Diagnosis

Because of the typical association of PFUI with more serious concomitant injuries, above all else resuscitation and stabilization of the patient is paramount. When the mechanism of injury portends a possible PFUI, the triad of blood at the

meatus, inability to urinate, and a palpably full bladder may indicate a urethral disruption. Because these classic signs or others (a "high-riding" prostate or perineal hematoma) may be clinically absent, a PFUI is often first suspected when a urethral catheter cannot be placed into the bladder.[22] When a PFUI is suspected, an immediate retrograde urethrogram can aid in the diagnosis.

Management

Debate continues regarding whether primary endoscopic realignment (PER) or suprapubic tube (SPT) diversion (with delayed posterior urethroplasty) is better for acute management of PFUI. There is no consensus among experts, with varying literature regarding the impact of each on eventual incontinence, impotence, and urethral stricture rates.[23–37] The obvious benefit of primary alignment is the potentially lower stricture rate of 56% versus the 97% seen with suprapubic catheter placement alone;[37] however, a more recent series reported that PER is only successful in 21% (4/19) of patients.[34] Additionally, a recent report of a large series showed that strictures that form after realignment can be shorter and therefore potentially easier to treat when undergoing urethroplasty, though this too remains controversial.[32]

While PER and SPT placement are currently both acceptable for the acute management of PFUI, placement of an SPT, with definitive and durable treatment via posterior urethroplasty 2 months postinjury, can avoid a prolonged and complicated clinical course to establishing urethral patency.[38] Additionally, in the setting of a severely injured or unstable patient, one should perform percutaneous SPT placement as the more expeditious procedure. This allows for stabilization and treatment of concomitant injuries, and the posterior urethroplasty can be performed electively in a controlled setting.

Complications

At the time of repair, complete excision of the fibrotic scar tissue is absolutely imperative, with outcomes directly related to complete scar removal (Fig. 15.2).[39] After a posterior urethroplasty, 5–15% of patients can experience recurrent stenosis at the anastomosis.[40–43] However, as the majority of the fibrotic scar tissue has been excised, endoscopic treatment (with a direct vision internal urethrotomy) has proven successful in managing these patients.

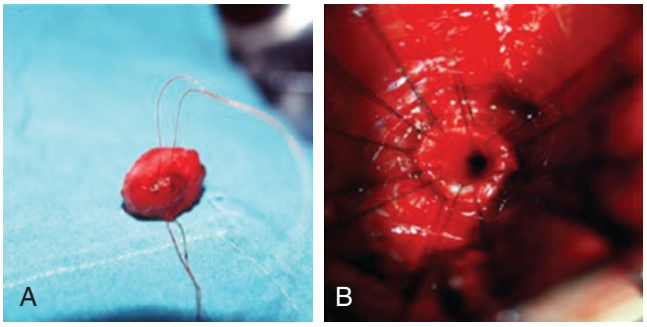


Figure 15.2 During the posterior urethroplasty for a PFUI, complete excision of the fibrous scar (A) that results from hematoma resorption is imperative to a successful outcome, allowing for precise mucosal apposition of healthy urothelium (B).

Erectile dysfunction (ED) commonly results following pelvic fractures, with an average rate of about 50%,[41,44–46] and reported as high as 82%.[43] Similar to PFUI itself, the incidence of ED is related to the nature of the pelvic ring disruption itself.[47] The precise etiology of post-PFUI ED is unclear, but theoretically could include cavernosal nerve injury, arterial insufficiency, venous leak, and direct corporal injury, although in most cases the cause of ED is likely multifactorial.[48–50] The varying rates and causative mechanisms have relied mainly on individual study methods, rendering a meaningful conclusion impossible. Anatomically, the proximity of the erectile nerves and vessels to the mechanism of injury leads one to conclude that damage to either or both may be responsible. Additionally, neurogenic ED has been reported to improve with time, suggesting that neuropraxia rather than complete disruption may be a cause.[50]

Urinary incontinence is surprisingly rare following PFUI (<4%),[41] with redundancy of continence mechanisms helping to preserve continence in the vast majority of patients following PFUI. Both the bladder neck and urethral sphincter help to prevent involuntary urine leakage; following PFUI the urethral sphincter may be damaged, but only when the bladder neck is also injured will the patient be incontinent.[51] More recently, urodynamic data have shown that a significant proportion of patients will also have identifiable rhabdosphincter function following repair.[21] In patients with persistent incontinence, placement of an artificial urinary sphincter is recommended.

ANTERIOR URETHRAL INJURIES

The anterior urethra extends distally from the membranous urethra to the urethral meatus, with the penoscrotal junction dividing the shorter, proximal bulbar urethra from the longer, distal pendulous urethra. Given the external anatomic location, the anterior urethra is more susceptible to penetrating trauma (e.g., stab or gunshot wounds), but the majority of injuries involve blunt compression ("straddle") injuries, penile fractures with urethal disruption, or iatrogenic trauma (e.g., after Foley catheterization or endoscopic urethral surgery) (Fig. 15.3).

Compression of the bulbar urethra against the pubic bone, or a "straddle injury," is the most commonly encountered

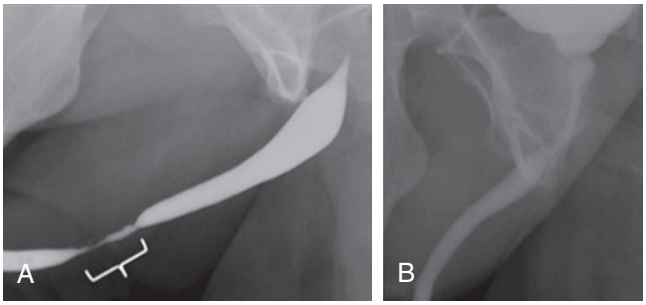


Figure 15.3 A retrograde urethrogram (A) of a patient who underwent endoscopic treatment of prostatic hyperplasia with laser vaporization. He presented 2 months later with obstructive voiding, and a pendulous stricture was found (bracket). This failed one dilation and given its location and 2.5-cm length, an overlapping buccal mucosa dorsal inlay and ventral onlay with pseudospongioplasty was performed, with excellent postoperative result on voiding cystourethrogram (B).

anterior urethral injury and occurs after a direct force to the perineum compresses the bulbar urethra against the pubic bone. Alternatively, penile constriction rings can damage the anterior urethra secondary to tissue ischemia while Foley catheterization or endoscopic urethral surgery can damage the bulbar urethra, resulting in contusion or partial urethral disruption. The true extent of iatrogenic injuries, along with trauma from constriction rings, may not become evident until many years after the original event.[52] Although rarely associated with pelvic fractures, anterior urethral injuries may be encountered in approximately 15% of penile fractures.[53]

Diagnosis

A careful history and physical examination should raise suspicion for anterior urethral injury, as these insults may arise immediately or after a substantial period of time. Straddle injuries often present in a delayed fashion with obstructive voiding symptoms and an idiopathic etiology. In a large series of 78 patients with straddle injuries, Park and McAninch reported great variability in the time to presentation with 40% of patients presenting to the emergency department in an acute setting and 60% of patients presenting 6 months to 10 years after the original injury.[54] Hematuria, penile sleeve hematoma (injury confined to Buck's fascia), difficulty voiding, and perineal "butterfly" hematoma (injury penetration of Buck's fascia) are common presenting symptoms in the acute setting. In addition to a perineal "butterfly" hematoma, penetration of Buck's fascia can allow the spread of urine and/or blood to the scrotum (dartos fascia), anterior abdominal wall (Colles fascia), and/or thighs (fascia lata). In patients with a suspected anterior urethral injury, a retrograde urethrogram should be performed. Flexible cystoscopy may also be utilized to aid with the diagnosis of urethral trauma, although radiographic imaging is usually sufficient for a diagnosis of urethral trauma.

Management

Anterior urethral injuries are classified into three groups based upon radiographic, clinical, or endoscopic findings. Though *contusions* may appear normal on retrograde urethrogram, these injuries are best determined with clinical suspicion through cystoscopy in the setting of a "normal" retrograde urethrogram. Alternatively, *partial disruptions* appear as extravasated urine on retrograde urethrogram with visualization of contrast in the urethra or bladder proximal to the injury. *Complete disruptions* appear as total extravasation without visualization of contrast in the more proximal urethra or bladder.

Contusions to the anterior urethra should be managed with a urethral catheter for approximately 2 weeks followed by a voiding cystourethrogram (VCUG) to confirm urethral patency. The patient should be counseled on the possibility of delayed development of a urethral stricture at the site of contusion.

Partial urethral disruptions diagnosed by retrograde urethrogram may be managed via various algorithms. Urinary diversion (via SPT) with formal repair after a minimum of 2 months allows resolution of inflammation and maturation of scar tissue. Although some experts support one attempt at Foley catheter placement, the possibility of causing a complete urethral disruption during this attempt should be considered. If urethral catheter placement is unsuccessful, percutaneous suprapubic tube placement should be performed. The preservation of urethral mucosa with partial disruptions may be adequate for re-epithelialization and eventual luminal recanalization; however, this requires periodic evaluation with uroflow studies and counseling regarding the possibility of future stricture development.

In patients with a complete disruption, either immediate or delayed repair can be considered, depending on any concomitant injuries or surgeon experience. In straddle injuries of a lesser degree, primary anterior urethral alignment alone has shown promising results with respect to stricture rate and ED.[55,56] In patients with low-velocity gunshot wounds, primary repair is recommended, as catheter placement alone results in far worse stricture rate.[57] Limited debridement of the corpus spongiosum should be performed in these cases, as the robust corporal blood supply allows for spontaneous healing of most contused areas.[58,59] In high-velocity gunshot wounds, SPT diversion and delayed repair should be undertaken, as the degree of tissue damage is greater in these patients.

Complications

As the risk of ED and incontinence are much lower in anterior compared to posterior urethral injuries, the major complications relating to anterior urethral trauma include urethral stricture formation and infection. If untreated, persistent extravasation of infected urine or blood may lead to urethrocutaneous fistula, urethral abscess, or urethral diverticula. Prolonged urine extravasation into the corpus spongiosum may also lead to added spongiofibrosis, resulting in a longer urethral stricture. Consequently, a longer anterior urethral stricture necessitates more complex management with a buccal mucosa graft (BMG) or fasciocutaneous flap.

Patients with resultant urethral strictures are often subjected to endoscopic procedures such as dilations or urethrotomies that frequently need to be repeated. Such interventions can subject patients to pain and complications negatively impacting quality of life.[60] The success rate of dilations is also low, with most patients eventually requiring definitive urethral repair.

In patients with recurrent strictures following urethroplasty, direct visualization and incision of the urethra (DVIU) may be considered for singular bulbar stenoses that are < 1 cm and recur > 6 months following the initial procedure. In this setting, success rates of 9–52% can be achieved; however, longer, multiple, penile, or distal strictures do not respond to repeat dilation/incision.[61–66] In patients with long (>3 cm), complex, or multifocal recurrent strictures, substitution urethroplasty with either buccal mucosa grafting or penile skin flaps is necessary (Fig. 15.4). However, typically, patients who fail urethroplasty suffer from a focal, short-segment stricture, which can be effectively treated with anastomotic techniques, with excellent success rates of up to 93%.[67]

In order to optimize success of urethroplasty, several aspects need to be considered. Above all, complete excision of all scar tissue must be assured. In the reoperative setting, it is common to find that the stenosis extends proximally to virgin tissue planes, indicating inadequate

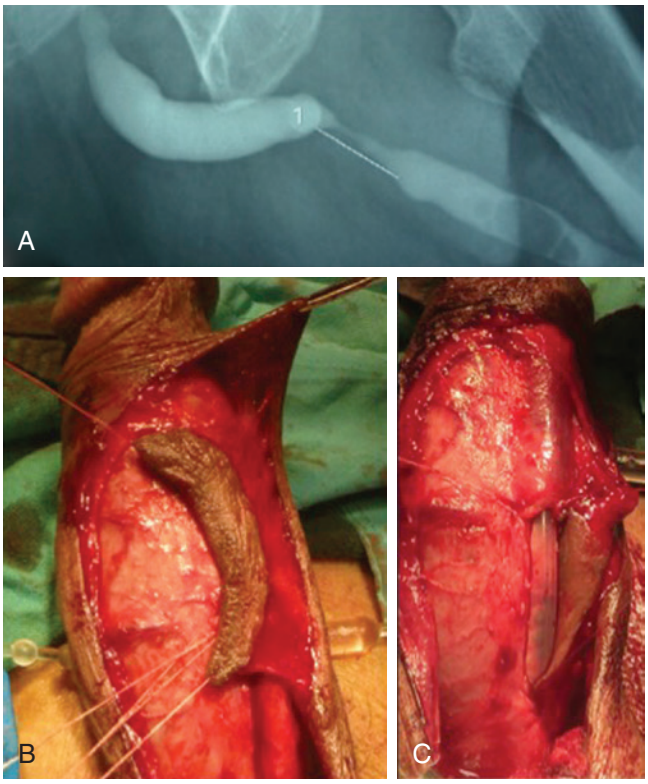


Figure 15.4 Retrograde urethrogram (A) of a patient with a pendulous stricture following a transurethral procedure. After failing previous attempts at dilation, an Orandi penile skin flap was mobilized (B) and used as a substitution for the scarred segment (C).

proximal dissection during the initial procedure. In order to best achieve complete scar excision, precise control of the proximal urethral lumen can be facilitated by preoperative guidewire placement or antegrade instrumentation via a SPT tract (when available).[67] The distal-most extent of the scar is easily identified with urethroscopy and visualization or palpation of the scope at the site of the stricture.[68]

After the urothelial scar is excised, the surrounding fibrotic tissue must also be removed. Often, scalpel dissection is required as scissors may not be effective in cutting the dense fibrosis encasing the urethra. For these reasons, excisional techniques may be superior to nontransecting methods, as scar tissue is more developed in the reoperative setting.

External Genitalia

PENILE FRACTURES

Etiology and Management

Due to its external location and relative mobility, penile injuries are uncommon. Blunt injury typically occurs only with an erect phallus, when the resilient tissues of the tunica albuginea can be compromised, as in a penile fracture. Generally, penile fractures occur from vigorous sexual or masturbatory techniques, such as when the rigid phallus slips out of the vagina and strikes the perineum or pubic bone. Intracavernosal pressures must exceed 1500 mm Hg in order for fracture to occur, such as when the erect penis bends abnormally and the intracavernosal pressure exceeds the tensile strength of the tunical tissue.[69]

The injury is usually a transverse tear in the tunica albuginea, typically 1–2 cm in length, and generally located ventrolaterally (where the tunica is the thinnest) distal to the suspensory ligament.[53,70] Diagnosis is often straightforward and can be made reliably with history and physical examination. A popping sound is often heard, followed by pain, immediate detumescence, and penile ecchymosis ("eggplant deformity"). Because of the psychosocial implications of the injury, patients are often embarrassed and can delay their presentation to the emergency room or clinic.

Urethral injuries can occur with penile fractures, reportedly as often as 24%.[71] A high index of suspicion should be given to patients with blood at the meatus, microscopic or gross hematuria, or difficulty voiding. Retrograde urethrography can be inaccurate and time-consuming, thereby delaying operative repair.[72] As the patient is likely undergoing operative repair of the tunical defect, direct visualization with flexible urethoscopy should be performed to evaluate the urethra. If a urethral defect is found, open repair should be undertaken with care to excise injured tissue and precise urothelial reapproximation.

In cases that are clinically unclear, such as when the history and physical exam are incongruent, imaging may be considered to evaluate the tunical integrity. Magnetic resonance imaging has been proven as a noninvasive and accurate method of demonstrating tunical defects,[73] but the test is expensive and time-consuming. Ultrasound is a more widely available modality that can be readily performed and can assist surgeons in preoperative evaluation and planning[74] (Fig. 15.5).

Complications

Prompt diagnosis and treatment optimizes outcomes and reduces complication rates. If treated within 8 hours of injury, patients have significantly better results than with delayed (>36 hours) repairs.[70] Penile curvature occurs in less than 5% of patients if treated surgically, while conservative management yields curvature rates in excess of 10%, abscess or plaques in 25–30%, and prolonged hospital stays.[75–78] A feared complication is prolonged erectile dysfunction, as the integrity of the corpus cavernosum is compromised. However, this too can be minimized, with erectile function rates similar to those of controls when fractures are promptly treated surgically.[79]

PENILE AMPUTATION

Etiology and Management

Penile amputation is quite rare and is usually the result of genital self-mutilation. The vast majority (65–87%) of these patients suffer from pyschosis, and psychiatric consultation should be obtained in all cases.[80,81] The best results are achieved with reanastomosis of the corporal bodies and the urethra, along with microsurgical repair of the dorsal penile vessels and nerves (Fig. 15.6). If microsurgical support is not available, reapproximating the corpora cavernosa and the urethra can suffice, with the potential for loss of penile skin and sensation.

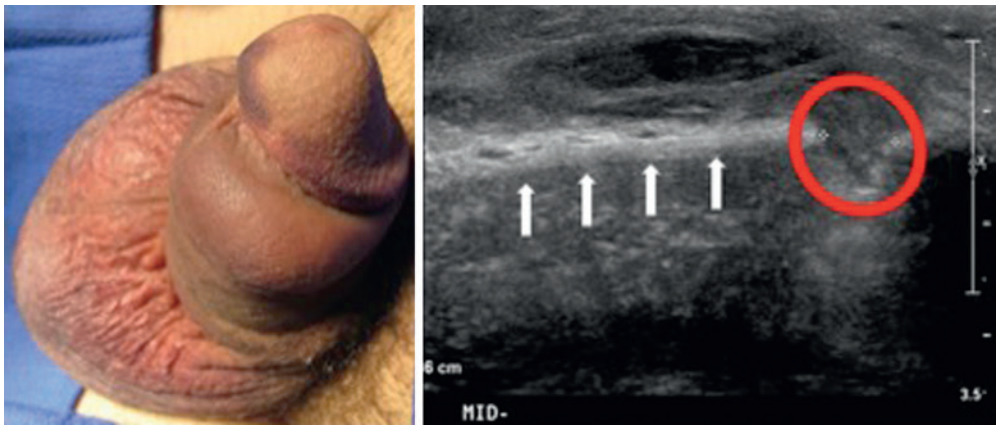


Figure 15.5 A case of a patient who presented 1 week following a penile injury sustained during intercourse. He did not lose his erection and had been able to engage in intercourse since the injury. His exam showed mild ecchymosis and swelling, but given his history, an ultrasound was performed. It clearly showed the tunica albuginea (arrows) and a defect (circle) consistent with penile fracture. Operative exploration confirmed the injury and the defect was repaired.

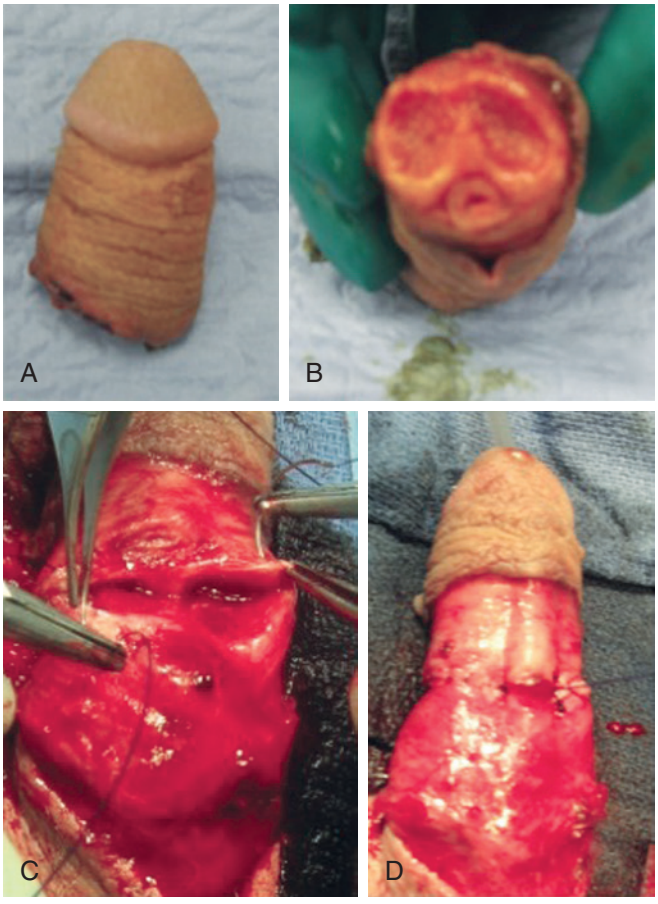


Figure 15.6 Self-amputation of a penis in a psychotic patient. The distal end (A) was found and preserved in a "double-bag" technique and transported with the patient. The proximal stump was cleaned and all devitalized tissue was debrided. The corpora cavernosa were then reapproximated (C) and the urethra was closed over a Foley catheter (D). Microsurgical techniques were used to reconnect the dorsal neurovascular structures.

The severed end of the penis should be preserved by rinsing with saline, wrapping in saline-soaked gauze, and placement in a sterile plastic bag. This bag is then placed in an outer bag filled with ice and transferred along with the patient.[82] Direct contact with ice for a prolonged period can result in hypothermic injury, and if care is taken to transport the severed end carefully, replantation can be successful after 16 hours of cold or 6 hours of warm ischemia time.[83]

Complications

The most common potential complications of penile reattachment surgery are loss of the distal segment (either from vascular compromise or repeated self-mutilation), penile numbness, and erectile dysfunction. Careful attention to the neurovascular anastomoses with microsurgical techniques helps establish blood flow and enables nerve regeneration. Return of erectile function is possible in about 50% of patients with either a macroscopic or microscopic repair; however, complications of urethral strictures and skin or sensation loss are decreased with microvascular repair.[82]

TESTICULAR TRAUMA

Diagnosis and Management

Scrotal ecchymosis and swelling, along with difficulty palpating the testicular contour on exam, can suggest a testicular rupture following blunt or penetrating scrotal trauma. Immediate exploration may be considered, if the mechanism and clinical exam are consistent with rupture. In delayed or unclear cases, ultrasound may aid in diagnosis (Fig. 15.7).

Ultrasound is the modality of choice in evaluating for testicular injury. The most common specific finding is loss of testicular contour with heterogeneous parenchymal echotexture.[84] Early exploration and repair should be undertaken to prevent complications arising from rupture of the tunica albuginea.

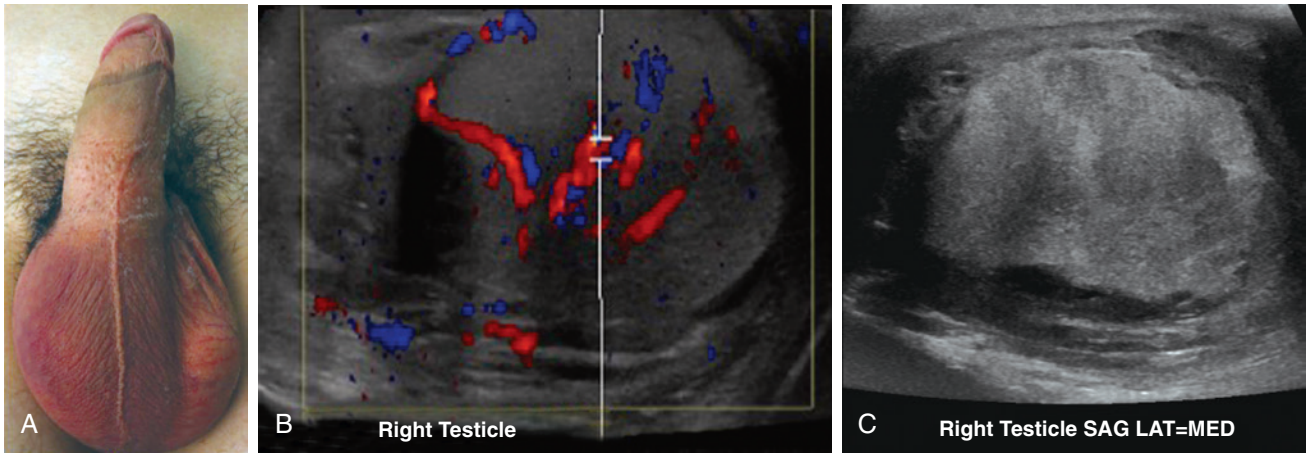


Figure 15.7 A 15-year-old patient sustained a scrotal injury with a lacrosse ball (not wearing genital protection). His exam (A) showed a tender, ecchymotic hemiscrotum, and sonogram (B) confirmed presence of arterial flow to the right testicle. Note the loss of contour and parenchymal heterogeneity that are signs indicating testicular rupture (C).

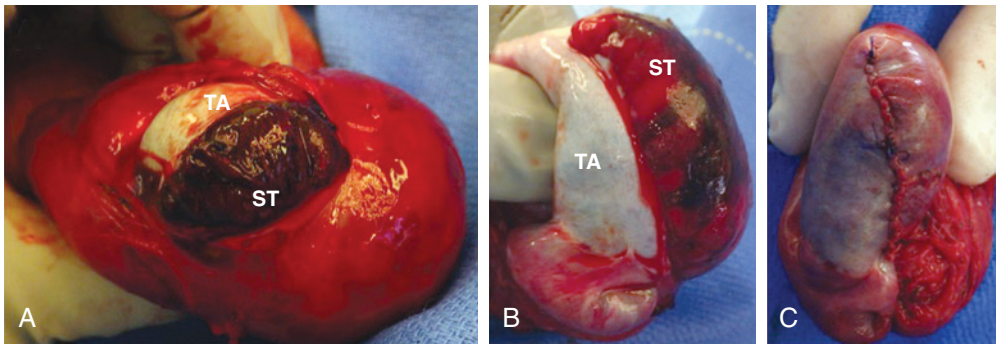


Figure 15.8 Scrotal exploration (A) revealed a defect in the tunica albuginea (TA) with extrusion of seminiferous tubules (ST). The linear tear extended along the entire longitudinal axis of his right testis (B). After debridement of any nonviable tissue, the tunica albuginea was closed with 5-0 PDS suture (C), preserving approximately 75% of his testicular volume, with arterial flow confirmed by Doppler signals.

Complications

Prevention of complications is best achieved by prompt recognition and repair of any tunical defects, with debridement of devitalized parenchyma (Fig. 15.8). This minimizes the chance for testicular atrophy from ischemia and infection.[85] If the injury is not diagnosed and treated promptly, the chance for testicular loss increases significantly, as well as potential infertility issues due to the development of antisperm antibodies resulting from the exposure of seminiferous tubules to systemic blood.

Repair should consist of debriding all nonviable tissue and closure of the tunica albuginea whenever possible. In cases where the tunica albuginea is not viable or too damaged to close primarily, a tunica vaginalis graft can be considered to cover the defect.[4] In cases where the initial trauma is penetrating in nature, immediate exploration is recommended to reduce complications.

References

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Chapter 15 Questions

1. The most common genitourinary organ injured is the:
   a. Ureter
   b. Bladder
   c. Kidney
   d. Testicles
   e. Prostate

2. 48 hours after a patient sustained a blunt abdominal injury that initially showed a renal laceration, she develops fever and flank pain. She is hemodynamically stable. The next step is:
   a. Observation
   b. Axial imaging
   c. Angiography
   d. Operative exploration
   e. Immediate nephrectomy

3. Axial imaging 48 hours after a blunt renal imaging in the patient above shows an enlarging urinoma. The next step in management is:
   a. Observation
   b. Repeat imaging
   c. Internalized ureteral stent placement
   d. Operative exploration and repair
   e. Nephrectomy

4. A patient sustains a gunshot wound to the left flank. He is stable, and imaging shows a through and through trajectory, with no intraabdominal injury. He is admitted for observation and, on the following day, develops left flank pain and hematuria. Serum creatinine is normal, but you suspect a missed ureteral injury. What is the best imaging study to evaluate initially?
   a. Plain film KUB
   b. Magnetic resonance imaging
   c. Ultrasound
   d. CT scan with IV contrast and delayed images
   e. Lasix renogram

5. In a stable patient with a penetrating ureteral injury diagnosed 24 hours after the initial trauma, options for management include:
   a. Observation
   b. Ureteral stent placement
   c. Percutaneous nephrostomy with delayed repair
   d. b and d
   e. All of the above

6. Which of the following statements is true regarding bladder trauma?
   a. Intraperitoneal bladder ruptures can be observed, provided the patient is stable
   b. All extraperitoneal bladder injuries should be managed conservatively with a catheter for 2 weeks
   c. Bladder ruptures are best diagnosed with ultrasound, as it does not expose the patient to radiation
   d. If a patient is undergoing exploration for concomitant injuries, one should repair extraperitoneal bladder injuries, as this will reduce the complication rate
   e. A suprapubic catheter is always necessary when repairing a bladder injury

7. The anatomic urethral segment that is most often injured concomitantly with a pelvic fracture is:
   a. Pendulous
   b. Bulbar
   c. Membranous
   d. Prostatic
   e. Fossa navicularis

8. When urethral injury is suspected in a trauma patient (i.e., blood at the meatus with inability to urinate), which is the appropriate next step?
   a. Retrograde urethrogram
   b. Catheter placement
   c. Cystoscopy with attempt at wire placement
   d. Operative exploration with urethroplasty
   e. Observation

9. When repairing a urethral distraction defect following a pelvic fracture urethral injury, the technical factor associated with the best long-term outcomes with lowest risk of recurrence is:
   a. Using a 12-suture anastomosis
   b. Complete excision of all fibrous scar tissue
   c. A 28Fr luminal caliber on both urethral ends
   d. Shorter operative time
   e. Surgery at a low-volume surgical center

10. The best initial management of a stable patient with a gunshot wound to the scrotum and no concomitant injuries is:
    a. Scrotal ultrasound to confirm injury
    b. Immediate exploration and repair
    c. MRI of the scrotum
    d. Observation
    e. Retrograde urethrogram

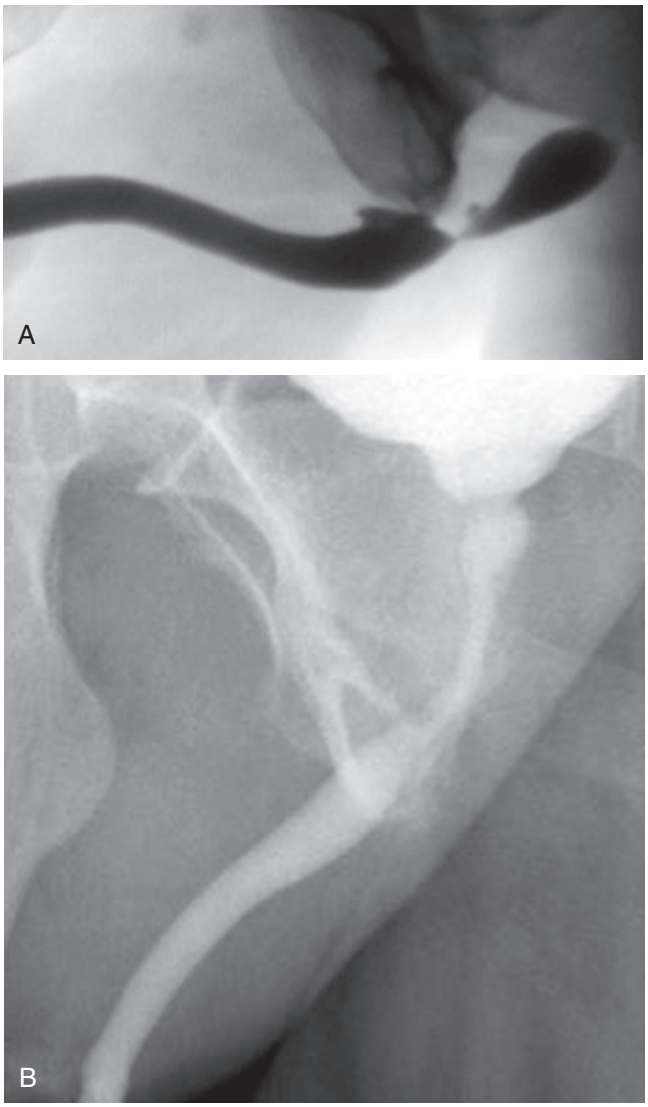
Case Studies

CASE 1

In 2006, an active duty soldier sustained a straddle injury and a bulbar urethral stricture developed over several months. He underwent an anastomotic urethroplasty, which remained patent for 4 years. However, in 2010 his stricture recurred and he failed two DVIUs and a dorsal inlay buccal mucosa graft (BMG), which failed immediately. He then had a repeat ventral onlay BMG urethroplasty. He presented 4 years later with epididymitis and complaints of obstructive voiding. His retrograde urethogram is pictured (Case Fig. 15.1).

1. The best approach to treating this patient's stricture is:
   a. DVIU
   b. Scrotal skin flap urethroplasty
   c. Split-thickness skin graft urethroplasty
   d. Repeat BMG urethroplasty
   e. Excision and primary anastomosis (EPA) urethroplasty

The patient underwent a reoperative EPA, with excellent urethral patency as shown in the VCUG Case Fig. 15.1, and to date has not experienced recurrence.



Case Figure 15.1

2. What is the success rate of EPA urethroplasty in this patient?
   a. <25%
   b. 26–50%
   c. 51–75%
   d. >75%
   e. 0%

3. What is the success rate of DVIU or dilation in this patient?
   a. <25%
   b. 26–50%
   c. 51–75%
   d. >75%
   e. 0%

CASE 2

A 51-year-old man was stabbed by his wife in the left flank. He was hemodynamically stable, and his urinalysis showed no red blood cells. His CT scans is in Case Fig. 15.2.

He had a grade 3 renal laceration with no urinary extravasation. He was clinically stable and discharged home on hospital day 3.

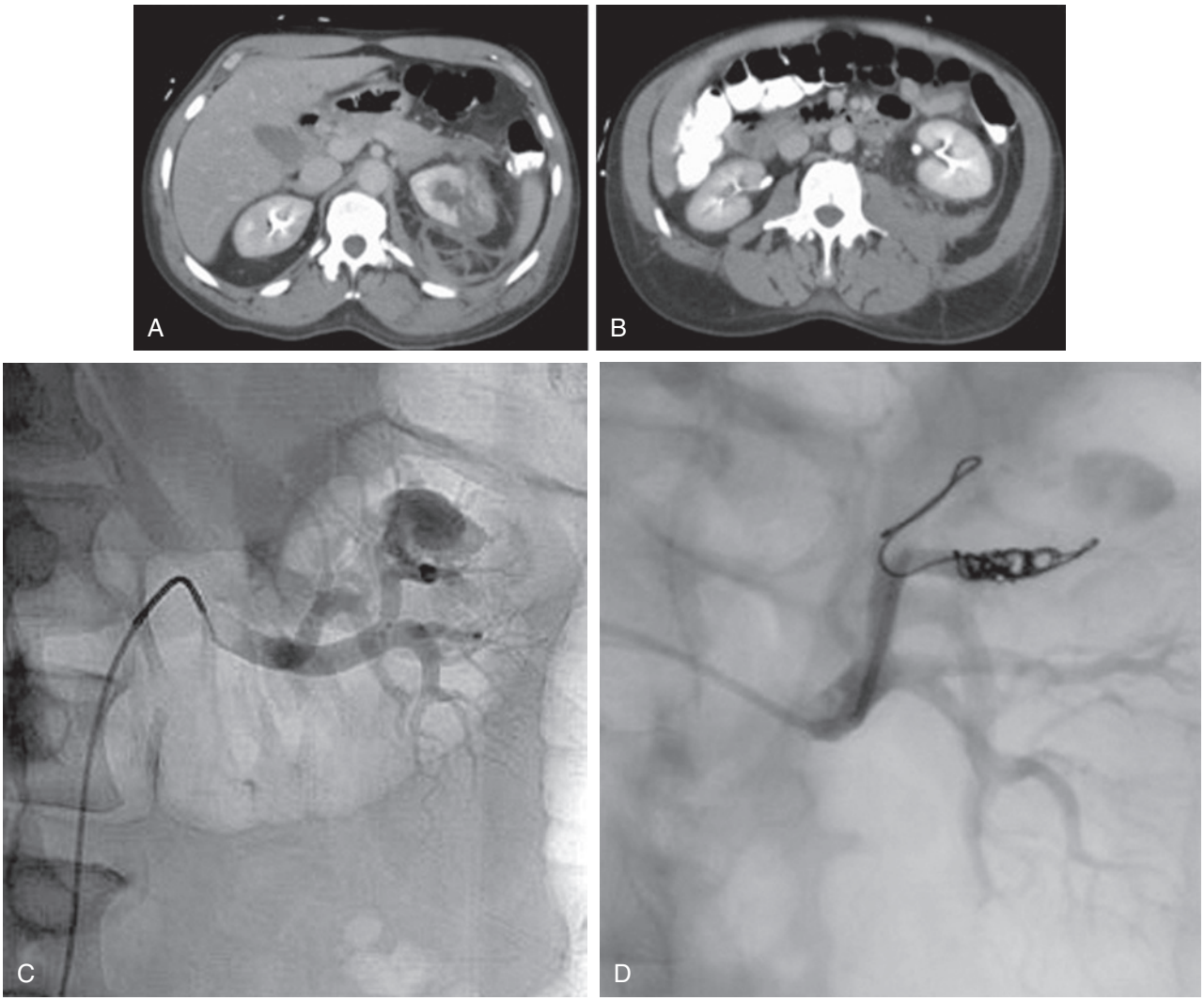
He then returned later the same day with gross hematuria. Hematocrit was 24%. Repeat CT scan with delayed images were largely unchanged, with no extravasation of contrast from either vascular or urinary structures. Over the course of 12 hours, his hematocrit dropped to 21%, and though he remained hemodynamically stable, an arteriogram was performed.

1. What is the diagnosis?
   a. Renal cell carcinoma
   b. Missed renal artery injury
   c. Pseudoaneurysm
   d. Missed collecting system injury
   e. Renal infection

2. What is the treatment for posttraumatic pseudoaneurysm?
   a. Open exploration
   b. Endovascular embolization
   c. Ureteroscopy and cauterization
   d. Observation
   e. Endovascular stenting

Answers

1. **c.** Injury to the kidneys is the most common genitourinary trauma encountered, accounting for 24% of traumatic abdominal solid organ injuries.
2. **b.** The current American Urological Association guidelines on urotrauma now advocate for noninvasive management of any patient with a renal injury who is hemodynamically stable, and compulsory intervention (either endovascular or surgical) in unstable patients with poor response to resuscitation. Contrast-enhanced CT scanning, with delayed images, remains the most common method for evaluating both vascular and collecting system trauma.
3. **c.** In patients with a persistent urine leak on repeat imaging (48 hours later), or with complications such as enlarging urinoma, fever, pain, ileus, fistula, or infection, urinary drainage with an internalized ureteral stent should be performed.
4. **d.** In cases where ureteral injury is suspected, intravenous contrast-enhanced axial imaging with delayed films is recommended, or direct visualization during laparotomy if no preoperative imaging is available.
5. **d.** Either a stent or percutaneous nephrostomy (if a stent cannot be placed) can divert the urine from a partial or delayed presentation of a ureteral injury, with a definitive repair at a later date, when the patient has recovered from the acute trauma.
6. **d.** While extraperitoneal bladder ruptures are typically managed with urethral catheter drainage alone, if the patient is undergoing a laparotomy for concomitant injuries, complication rates are lower if the bladder is repaired during the operation.
7. **c.** Injuries of the posterior urethra are typically "disruption" type injuries, usually occurring in conjunction



Case Figure 15.2

with multisystem trauma such as motor vehicle accidents, falls, or industrial accidents. These injuries are almost always encountered in conjunction with fracture of the anterior pelvic ring or pubic diastasis, with the degree of displacement correlated to a higher risk of urethral injury. Conversely, only 10–15% of pelvic fractures are associated with urethral injury.

8. **a.** In all patients suspected of a urethral injury due to blood at the meatus, inability to pass a catheter, perineal or penile hematoma, or high riding bladder on imaging, a retrograde urethrogram should be performed for evaluation of the urethra.
9. **b.** Following a pelvic fracture distraction injury, the resultant hematoma is replaced by fibrous scar tissue. The most important step in ensuring success of a posterior urethroplasty is complete excision of this scar tissue.
10. **b.** Ultrasound is the modality of choice in evaluating for testicular injury. The most common specific finding is loss of testicular contour with heterogeneous parenchymal echotexture. Early exploration and repair should be undertaken to prevent complications arising from rupture of the tunica albuginea. In cases where the initial trauma is penetrating in nature, immediate exploration is recommended to reduce complications.

CASE 1

1. **d.** Given that he has failed two BMG urethroplasties, his risk of recurrence and oral complications is higher should another BMG be harvested. DVIU has a dismal success rate in this setting, and the other choices of substitution urethroplasty are suboptimal. Excellent success rates of revision surgery with EPA have been demonstrated, and particular attention must be given to complete excision of the scarred tissue, as this was likely the cause of the previous failures.
2. **d.** If the surgeon adheres to the principles of complete scar excision and precise mucosal apposition of healthy urothelial edges, the expected results can approach those of primary EPA urethroplasty, even in the reoperative setting.

3. **a.** In fact, current literature suggests that having failed two dilations renders DVIU completely ineffective (0%) in maintaining urethral patency.

CASE 2

1. **c.** The patient's axial imaging did not suggest injury to either the collecting system or vasculature, and as he has gross hematuria at this time, a pseudoaneurysm is the most likely diagnosis.

2. **b.** One of the benefits of arteriography for the evaluation of renal trauma is that intervention can be performed in the same setting. By selectively embolizing bleeding vessels, the remaining renal parenchyma can be spared. Open exploration would likely result in nephrectomy due to intraoperative hemorrhage, and endoscopic methods and observation would be ineffective.

   The patient underwent coil embolization of the pseudoaneurysm and recovered with preservation of his left kidney and renal function.

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SECTION III

Surgical Scenarios Predisposing to Complication

16 Urologic Surgery in the Obese

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CHAPTER OUTLINE

Condition-specific Considerations
Malignant Urologic Disease
Prostate Cancer and Radical Prostatectomy
Technical Considerations
Kidney Cancer, Nephrectomy, and Partial Nephrectomy
Technical Considerations
Bladder Cancer
Technical Considerations
Lower Urinary Tract Symptoms
Erectile Dysfunction
Urolithiasis
Conclusions
Chapter 16 Questions and Answers

KEY POINTS

1. Obesity is a substantial, growing problem with broad medical impact.
2. Obesity has and important pathophysiologic impact on many urologic diseases.
3. Surgery in obese patients introduces unique issues which should be addressed to optimize outcomes.

In the decades obesity has quickly become a major worldwide problem. Worldwide, obesity has more than doubled since 1980, with estimates of nearly 2 billion people being at least overweight. In the United States, it is estimated that more than one-third of adults are obese and a staggering two-thirds of adults are at least overweight. Some estimates suggest that nearly 1 in 5 deaths in the United States can be attributed to obesity.[1] The incidence of obesity has nearly tripled in just over 50 years and continues to increase.[2] Fig. 16.1 illustrates the actual and predicted prevalence of obesity through 2030. It has been suggested that if the prevalence of obesity continues to rise at the current pace it could ultimately lead to a decline in life expectancy, which has not taken place in the last 2 centuries.[3]

The health implications of obesity are enormous, as obesity is a well-established risk factor for a number of chronic conditions, including type 2 diabetes and cardiovascular disease. In addition, obesity contributes to the increased incidence of death from several malignancies. Largely as a result of these multiple comorbid conditions, medical care comes at a significantly increased economic cost for the obese. In 2006, medical costs for an obese patient were $1429 higher, or 42% more, than that of a normal-weight patient.[4]

The World Health Organization (WHO) defines the terms *overweight* and *obese* as excessive fat accumulation presenting a risk to health. The most commonly used anthropometric measure of obesity is body mass index (BMI), which is a weight (in kilograms) divided by the square of height (in meters). The assumption of BMI is that adiposity is not reliant on height. The WHO has defined a BMI greater than 25 as overweight and greater than 30 as obese. The WHO classification of BMI is listed in Table 16.1. The validity of BMI has been supported by multiple studies that have shown correlation to densitometry estimates of body fat composition.[5] BMI may be a less reliable measure of central obesity, and as a result measures of waist-to-hip ratio and waist circumference have been used in several epidemiologic studies. Using BMI as a measure of obesity is certainly not perfect, but it is easily calculated and by far the most commonly used standard.

As the prevalence of obese patients continues to increase, so will the number of obese patients seeking urologic care. Compounding the issue is that obesity can increase the risks of several urologic diseases, including kidney cancer, aggressive prostate cancer, urolithiasis, and lower urinary tract symptoms (LUTS). More now than ever urologists must be aware of the challenges associated with caring for and operating on overweight and obese patients.

Condition-specific Considerations

MALIGNANT UROLOGIC DISEASE

Obesity as a risk factor for cancer first garnered attention as a result of a number of epidemiologic studies in the 1970s–1980s. Obesity has been linked to the development of a number of malignancies, most notably colon, breast (postmenopausal women), endometrial, esophageal, and kidney cancer. It has been estimated that 15–20% of all cancer deaths in the United States can be attributed to overweight and obesity.[6]

The biologic mechanisms linking obesity to cancer are not well understood, but likely involve the alterations obesity causes in metabolism and endocrine activity, as well as to peptide and steroid hormone production. Insulin resistance and hyperinsulinemia resulting from increased

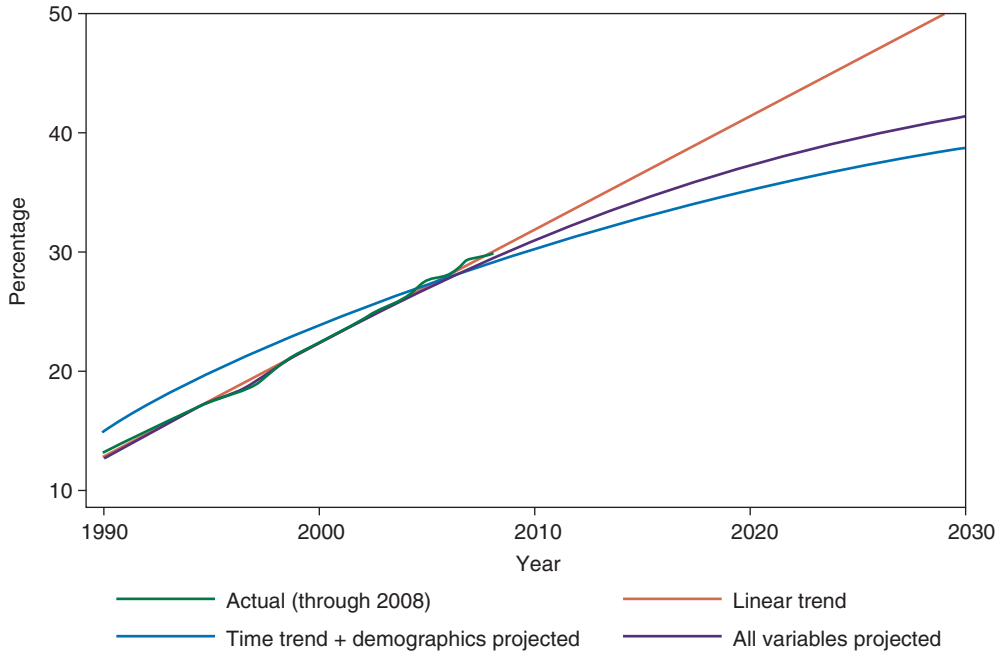


Figure 16.1 Actual and predicted prevalence of obesity (BMI ≥30) (From Finkelstein EA, et al. Obesity and severe obesity forecasts through 2030. American Journal of Preventive Medicine 2012;42.6:563-70.)

Table 16.1 The International Classification of Adult Underweight, Overweight and Obesity According to BMI

Classification	BMI(kg/m²)
Underweight	<18.50
Severe thinness	<16.00
Moderate thinness	16.00–16.99
Mild thinness	17.00–18.49
Normal range	18.50–24.99
Overweight	≥25.00
Pre-obese	25.00–29.99
Obese	≥30.00
Obese Class 1	30.00–34.99
Obese Class 2	35.00–39.99
Obese Class 3	≥40.00

(Adapted from WHO, 1995, WHO, 2000, and WHO 2004. World Health Organization. Obesity: preventing and managing the global epidemic. No. 894. World Health Organization, 2000.)

circulating levels of free fatty acids may play an important role in the development of several cancers. Insulin promotes synthesis of the hormone insulin-like growth factor 1 (IGF1), which has been shown to promote cell proliferation and inhibit apoptosis.[7] Additional support for hyperinsulinemia as a risk factor for cancer development lies in the association of many cancers with type 2 diabetes, which is typically associated with long-term insulin resistance and hyperinsulinemia.

Beyond the association with aggressive disease, obesity has a major influence on the surgical approach to urologic malignant disease. Commonly performed surgical procedures are found to be more difficult and complex among the obese, with an increased risk of perioperative complications, incomplete resection, and poor oncologic outcomes.

PROSTATE CANCER AND RADICAL PROSTATECTOMY

Obesity is a condition that can have a dramatic effect on sex hormones, specifically raising estrogen levels through increased aromatase activity and thus lowering testosterone levels. It is a logical step to think obesity may have an effect on the incidence of an androgen sensitive malignancy such as prostate cancer. Links between obesity and other sex hormone related malignancies, such as postmenopausal breast cancer and endometrial cancer, have been more clearly defined, but the data on prostate cancer and obesity are not as clear.

Several meta-analyses have been performed in regard to obesity and prostate cancer incidence with conflicting results. Some have found a weak positive correlation,[8] while others have found no significant effect.[9,10] As one might expect, the studies included in these analyses vary greatly in their findings, whether harmful or protective. Largely due to the heterogeneity of these findings and the lack of a consensus effect, prostate cancer has not typically been listed among malignancies in which obesity has a significant role.[5,11]

While overall incidence of prostate cancer may not be associated with BMI, there is a growing body of evidence that obesity is linked to particularly aggressive prostate cancer. A meta-analysis by MacInnis et al. found obesity increased risk for advanced disease with a relative risk (RR) of 1.12 (95%, CI 1.01–1.23) for every 5-unit increase in BMI.[8] Similarly, Discacciati et al. found an increased risk of advanced disease, RR = 1.09 (95%, CI 1.02–1.16), for every 5-unit increase in BMI while actually observing a protective effect in localized disease, RR = 0.94 (95%, CI 0.91–0.97).[12] This dual effect on localized and aggressive disease may help explain why no obvious relationship has emerged in regard to total incidence. An elevated risk of

aggressive disease, however, may help explain the association with increased risk of prostate cancer mortality in the obese. Calle et al. found a 34% increased risk of dying from prostate cancer with a BMI greater than 35 in a prospectively followed group of more than 900,000 people.[6] Similarly, in a meta-analysis performed by Cao et al., each 5 kg/m^2 unit increase in BMI increased risk of death from prostate cancer by 15%.[13]

Outcomes after radical prostatectomy seem to corroborate the notion that obesity may be associated with more aggressive disease. A multi-institutional review found obesity was associated with higher-grade tumors, a trend toward more positive surgical margins, and higher biochemical failure rates.[18] Similarly, data from the CaPSURE database showed increasing BMI was associated with biochemical recurrence, with very obese patients 1.69 times more likely to recur than normal-weight patients.[19] In addition, obese patients are less likely to regain urinary continence and sexual function after radical prostatectomy.[20–22]

Technical Considerations

Obesity can compromise both open and robotic-assisted prostatectomy techniques. In the case of open surgery, the depth of the incision compromises visibility and manual dexterity and limits the ability to expose neurovascular structures and the membranous urethral complex. A number of techniques have been implemented to improve apical exposure, including pubic osteotomy, but in general, when performing prostatectomy on obese patients, a generous incision, use of a multi-bladed fixed retractor, and surgical magnification are useful.

While robotic-assisted surgical techniques as compared to open surgery may allow better exposure of the deep pelvis and increased dexterity, obesity negatively impacts the technique as well. Obese patients are often unable to tolerate the steep Trendelenburg position due to increased airway pressure, diaphragmatic elevation, and difficulty with ventilation. Upon docking, arm movement can be made difficult by the presence of a large, protuberant abdomen, similarly limiting the reach of instruments to the deep pelvis. In these cases, careful port position selection, below the level of the most protuberant abdomen, can be helpful.

In approaching obese patients with prostate cancer, a recommendation for preoperative weight loss is reasonable, provided the patient's disease risk is not deemed to be excessive, risking progression upon delaying surgery. In general, patients who would benefit from radical prostatectomy have time for consideration of weight loss. If weight loss cannot be achieved, then alternative therapeutic approaches might be considered.

KIDNEY CANCER, NEPHRECTOMY, AND PARTIAL NEPHRECTOMY

Kidney cancer, specifically renal cell carcinoma, is one of the malignancies more firmly established as being associated with increased risk in the obese. The majority of epidemiologic studies have identified obesity as increasing the risk of renal cancer in a directly proportionate manner. Some have shown a greater risk for cancer in obese women compared to men, while others have shown a similar effect regardless of sex. A meta-analysis in 2001 of 11 studies found a relative risk of 1.06 and 1.07 for men and women, respectively, for each unit increase in BMI. This corresponds to a relative risk of 1.84 for an obese patient compared to a normal-weight patient.[23] In prospectively following more than 900,000 people, Calle et al. found that increased BMI correlated to an increased risk of death from kidney cancer of up to 70% in patients with BMIs greater than 35.[6] Hypertension and diabetes, both of which are commonly associated with obesity, are also established risk factors for kidney cancer. Despite possible confounding factors, obesity has been shown to increase risk of kidney cancer independent of hypertension.[24,25] With the majority of evidence showing a positive association, The International Agency for Research on Cancer, a part of the World Health Organization, has included kidney cancer among malignancies linked to obesity.

Like prostate cancer, obesity may have a large impact on how kidney cancer is surgically treated. This is an important point because more than half of patients undergoing surgery for kidney cancer will be at least overweight. The data are mixed on how obesity affects outcomes given the particular approaches for kidney surgery. Some data suggest obese patients have increased complications regardless of approach.[26] In the advent of laparoscopic surgery, obese patients were reported to have increased complications[26,27] and obesity was regarded as a relative contraindication to minimally invasive surgery. As experience increased, multiple reports showed similar outcomes among obese and nonobese patients.[28–30] Romero et al. compared open and minimally invasive partial nephrectomy in obese and nonobese patients and found obese patients undergoing open surgery had longer operative times, more blood loss, longer clamp times, increased complications, and longer hospital stays than did nonobese patients. In contrast, obese patients undergoing laparoscopic surgery had similar outcomes compared to nonobese patients except for greater blood loss.[31] A report using the National Surgical Quality Improvement Program from 2005 to 2012 showed patients undergoing laparoscopic partial nephrectomy had fewer overall complications than those undergoing open partial nephrectomy for all BMI categories, but the difference was largest for the morbidly obese, 22.2% versus 9.2%.[32] Robotic surgery has lowered some of the technical hurdles of laparoscopic partial nephrectomy, and many regard robotic partial nephrectomy as the procedure of choice for small renal masses. Obese patients undergoing robotic partial nephrectomy have similar outcomes compared to nonobese patients with the exception again of greater blood loss.[33,34]

Technical Considerations

In approaching the obese patient for renal tumor surgery, patient positioning is a critical consideration. Weight distribution during flank position can lead to increased risk of nerve injury, rhabdomyolysis, and compartment syndrome. Specific considerations for positioning are covered in Chapters 9, 31, and 37. In general, careful padding of the upper extremity; fixation of the arms, chest and pelvis; and avoidance of excessive flex can minimize positioning-related injuries. Elevation of the kidney rest should, likewise, be avoided to minimize pressure on the dependent muscles of the flank. In positioning the patient, either in full flank or

semi-oblique positions, the pelvis should be sufficiently rotated to distribute weight on the hip rather than the gluteal or presacral muscle compartments.

Mobilization of the kidney in the obese patient can present a unique challenge due to the abundance of perinephric fat and pericolic fat, as well as the depth of incision in the case of open surgery. Often fat surrounding the kidney can be inflamed, hypervascular, and adherent to the renal capsule. It is critical that the surgeon conduct the operation by first identifying critical anatomic structures surrounding the kidney, thereby minimizing the risk of inadvertent injury, and facilitating ultimate kidney mobilization for radical or partial excision. In the case of partial excision of the kidney, removal of excessive outer perinephric fat can aid in increasing mobility of the kidney during manipulation if partial nephrectomy is contemplated.

The decision for open versus laparoscopic renal surgery techniques is highly surgeon dependent. As in the case of other surgical procedures, open nephrectomy in the obese will likely require larger incisions, deeper exposure, and risk of perioperative morbidity as outlined below. Laparoscopic surgery should only be undertaken in the obese in the hands of experienced surgeons who can ensure that operative times are not excessive, in order to minimize the risk of positioning-related complications and pulmonary morbidity.

BLADDER CANCER

There is a general lack of evidence for a link between obesity and the incidence of bladder cancer. Several large epidemiologic studies fail to show an association between the two,[35–37] but there are limited data to support an association. Koebnick et al., using the NIH-AARP Diet and Health Study of nearly 500,00 people, found a positive correlation between BMI and bladder cancer with a relative risk of 1.28 (95%, CI 1.02–1.61) in those with the highest BMI.[38] Additionally, a meta-analysis of 11 cohort studies found a modestly increased risk of bladder cancer in the obese with a relative risk of 1.09 when controlled for smoking.[39] More recently, a systematic review of the literature by Cantiello concluded there is no consensus effect of BMI on the incidence of bladder cancer.[40] Perhaps more importantly, Calle et al. found no association between obesity and the risk of dying from bladder cancer in a cohort of more than 900,000 people.[6]

While there may not be consensus on whether obesity plays a role in the development of bladder cancer, there is evidence treatment is impacted in terms of outcomes and complications. In nonmuscle invasive bladder cancer, studies suggest obese patients have higher risks of recurrence, progression, and mortality.[41,42] In patients undergoing radical cystectomy, the obese have higher readmission rates, increased blood loss, and more complications,[43–45] specifically postoperative ileus[46] and parastomal hernia.[47,48] There are conflicting data regarding the impact of obesity on survival after radical cystectomy. In a multicenter review of over 4000 patients, Chromecki et al. found BMI >30 was associated with a higher risk of disease recurrence as well as disease-specific and overall mortality.[49] Other reports found no association.[50,51] Some reports suggest obese patients actually do better than normal-weight patients following radical cystectomy,[52,53] consistent with the "obesity paradox," or protective effect of obesity observed in a number of chronic conditions. Few would argue to advocate for increased levels of obesity for better outcomes after cystectomy; however, perhaps those with lower BMI, malnourishment, and lean muscle wasting are at greater risk. In a single institution series of patients undergoing radical cystectomy, Psutka et al. observed a protective effect in increased BMI, which was lost when adjusting for sarcopenia.[53]

Technical Considerations

Considerations for cystectomy in the obese patient are similar to those for prostatectomy. Exposure through wide incision and adequate retraction is essential, as is identification of critical vascular structures in the pelvis, prior to bladder mobilization. Urinary diversion can be particularly challenging in obese patients, owing to a thick, fat mesentery with limited mobility. Wide mesenteric incisions, to maximize bowel mobility, along with careful selection of bowel segment are essential. In forming a stoma, the Turnbull loop technique can be utilized if the bowel does not reach skin easily, as discussed in Chapter 45, but extending the distal mesenteric incision line may offer the most aid in lengthening of the segment.

LOWER URINARY TRACT SYMPTOMS

Obesity is a well-established risk factor for development of benign prostatic hyperplasia (BPH) and LUTS. In a longitudinal study of VA patients in 1985, Glynn et al. noted only BMI was a significant predictor of BPH.[54] More than a decade later, Hammarsten et al. found prostate size correlated with several components of metabolic syndrome, including not only obesity but also hyperinsulinemia, hypertension, and dyslipidemia.[55] Additional data have suggested BPH may be a consequence of metabolic syndrome, specifically from increased insulin levels.[55,56] Excess abdominal fat, or central obesity, is particularly recognized as a core component of metabolic syndrome. Correspondingly, Giovannucci et al. found that central obesity as measured by waist circumference was predictive of LUTS.[57] Multiple additional studies confirm this association.[56,58,59] In addition to being at higher risk for urinary symptoms, data suggest that patients with central obesity do worse following surgery for LUTS/BPH. Gacci et al. recently showed patients with a waist circumference greater than 102 cm are less likely to symptomatically improve, specifically in regard to storage symptoms after surgery.[60]

ERECTILE DYSFUNCTION

Sexual function is generally negatively impacted in the obese,[61] and erectile dysfunction (ED) is no exception. Obesity, and central obesity in particular, has been linked to ED in several studies.[62–64] ED is known to be multifactorial in origin, with vascular-, neurologic-, and endocrine-related etiologies. Obesity can have profound effects on each of these factors so an association with ED is not particularly surprising. Diabetes, of which obesity is a risk factor, can lead to microvascular compromise as well as autonomic neuropathy. Obesity is known to lower levels of testosterone and increase estrogens. Overweight and obese patients have

been estimated to have between a 1.5 and 3 times increased risk of developing ED.[65] Treatment of ED in the obese may be particularly difficult, especially in diabetics because pharmacologic therapy in these patients is not as effective. In a randomized trial, Esposito et al. demonstrated lifestyle changes and weight loss improved sexual function in up to one-third of obese men with ED.[66]

These observations are important when counseling men undergoing radical prostatectomy as the increased risk of ED in the obese population likely influences recovery of erections following surgery.

UROLITHIASIS

As the prevalence of obesity has dramatically increased in recent years, so has the prevalence of stone disease.[67] Epidemiologic studies have increasingly linked the two conditions. Using data from the Nurses' Health Study I and Health Professionals Follow-Up Study, Curhan et al. reported an increased risk of stone formation with higher BMI in women but not men.[68] A later report using the same datasets, in addition to the Nurses Health Study II, found BMI was associated with increased risk of kidney stone formation in both men and women, with obese men having a 1.33 and obese women having a 1.9–2.09 times increased risk of those with BMIs from 21 to 22.9. Moreover, weight gain itself was associated with increased risk of kidney stone formation, as was central obesity measured by waist circumference.[69] Reasons for increased risk of stones with obesity are likely multiple and associated with various components of metabolic syndrome. Hyperinsulinemia and resultant insulin resistance are associated with impairments in renal ammonium production,[70] with obese and diabetic patients shown to form more acidic urine.[71,72] Low urinary pH is an important risk factor for uric acid stones, but defects in renal acid handling may also lead to hypocitraturia.[73] Hyperinsulinemia can lead to increased urinary calcium excretion,[74] and both hypocitraturia and hyperinsulinemia increase the risk for calcium oxalate stones.

Obesity may further play an important role in which surgical treatment modality is chosen for stones. Current European Association of Urology guidelines state morbid obesity is an indication for open stone surgery, but few are eager to perform such procedures due to associated morbidity. Extracorporeal shock wave lithotripsy (ESWL) seems less effective in the obese.[75,76] Issues with ESWL in the obese may include poor fluoroscopic targeting and increased skin to stone distance.[75,77,78] In a systematic review of seven studies, Aboumarzouk et al. found a stone-free rate of 87.5% in patients with a mean BMI of 42.2 undergoing flexible ureteroscopy.[79] In expert hands, percutaneous nephrolithotomy (PCNL) in the obese has similar stone-free rates (SFR) with minimal complications,[80–84] although potentially with increased operative times and more radiation exposure.[84] A prospective review of 5803 patients from the Clinical Research Office of the Endourological Society (CROES) database showed PCNL could be done safely in the obese but resulted in lower SFR and more repeat procedures.[85] Several factors make PCNL challenging in the obese. From an anesthetic perspective, the prone position can compromise respiratory function and venous return, particularly in the obese.[86] Standard instrumentation and techniques may need modification due to the anatomy of the obese patient and increased skin to stone distance. Several strategies are suggested to improve success, including use of extra-long nephroscopes, long access sheaths, or suture tails to allow burying of sheaths within the subcutaneous fat.[83,87] Regardless of approach, surgical treatment of stones in the obese requires both surgeon experience and the thoughtful analysis of all available options (Table 16.2).

Table 16.2 Impact of Obesity on Urologic Conditions

	Increased Risk	Impact on Treatment
Prostate cancer	Overall: ↔ Aggressive disease: ↑	■ Higher risk of recurrence ■ Less likely to regain continence and sexual function
Kidney cancer	↑↑	■ Minimally invasive surgery may result in fewer complications
Bladder cancer	↔	■ May have worse outcomes after treatment for NMIBC ■ Blood loss, ileus, readmissions may be increased ■ Late complications such as parastomal hernia and ureterointestinal stricture may be increased
Lower urinary tract symptoms	↑	■ Surgery may not be as effective, specifically in regard to storage symptoms
Erectile dysfunction	↑	■ Oral agents may be less effective in those with diabetes
Urolithiasis	↑↑	■ ESWL less effective ■ PCNL may be challenging

NMIBC, non-muscle invasive bladder cancer; ESWL, extracorporeal shockwave lithotripsy; PCNL, percutaneous nephrolithotomy

Conclusions

Obesity has become a major medical problem that continues to grow. It has important associations with a number of chronic medical conditions. In urology, obesity is most strongly associated with increased risk of kidney cancer and is also linked to aggressive prostate cancer, urolithiasis, LUTS, and ED. Surgery in the obese is associated with higher risk of positioning complications, wound complications, and venous thromboembolism. Additionally, obese patients may have worse outcomes following some procedures such as prostatectomy. These risks, along with surgeon expertise and experience, should be carefully considered prior to surgery on the obese patient.

References

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Chapter 16 Questions

1. According to current data, the prevalence of which urologic disease is least associated with obesity?
   a. Advanced prostate cancer
   b. Bladder cancer
   c. Kidney cancer
   d. Urolithiasis
   e. Lower urinary tract symptoms

2. Which peripheral nerve is most likely to be injured perioperatively?
   a. Ulnar nerve
   b. Peroneal nerve
   c. Brachial plexus
   d. Obturator nerve
   e. Femoral nerve

3. The mainstay of treatment for well leg compartment syndrome is:
   a. Fluid resuscitation
   b. Antibiotics
   c. Intermittent compression devices
   d. Fasciotomy
   e. Anticoagulation

4. All of the following comorbidities have been associated with obesity except:
   a. Obstructive sleep apnea
   b. Type 2 diabetes
   c. Risk of stroke
   d. Coronary artery disease
   e. Ureteropelvic junction obstruction

5. Obese patients may be less likely to resolve which symptoms after surgery for lower urinary tract symptoms (LUTS)?
   a. Storage symptoms
   b. Emptying symptoms
   c. Storage and emptying symptoms
   d. None, they do just as well as the nonobese
   e. Surgery for LUTS in the obese is contraindicated

6. Which closure method is best to reduce the rate of incisional hernia?
   a. Large bite interrupted with a braided suture
   b. Small bite running with a monofilament suture
   c. Large bite running with a braided suture
   d. Small bite interrupted with a monofilament suture
   e. Large bite running with a monofilament suture

7. Which of the following is/are risk factors for the development of well leg compartment syndrome?
   a. Lithotomy position
   b. Trendelenburg position
   c. Hypotension
   d. Obesity
   e. All of the above

8. Reasons for increased stone formation in the obese include:
   a. Impairments in renal ammonium production
   b. Hypocitraturia
   c. Increased urinary calcium excretion
   d. Decreased urinary pH
   e. All of the above

9. According to recent estimates, approximately what proportion of the US population is obese?
   a. ⅓
   b. ⅔
   c. 1/2
   d. 1/10
   e. 4/5

Answers

1. **b.** While prostate cancer has not been formally listed as a disease for which obesity has a significant role, obesity has been linked, in many studies, with an increased risk of advanced prostate cancer. The World Health Organization lists kidney cancer as a malignancy related to obesity. Both urolithiasis and lower urinary tract symptoms are linked to obesity, while bladder cancer has never been shown to have a link.
2. **e.** The ulnar nerve is most commonly injured and is an increased risk in the obese. The ulnar nerve is vulnerable to compression in the cubital tunnel at the elbow and protection requires support of the arm and careful padding of the elbow.
3. **d.** Compartment syndrome is a rare and potentially catastrophic complication requiring prompt clinical diagnosis and treatment. When this occurs in a nontraumatized, otherwise healthy lower limb, it is termed *well leg compartment syndrome* (WLCS). Measurement of intracompartmental pressures (ICP) confirms diagnosis, and the general consensus is that ICP within 20 mm Hg of diastolic is an indication for fasciotomy.
4. **e.** Ureteropelvic junction obstruction has not been linked to obesity, while all other listed operative comorbidities are observed with greater frequency among obese patients.
5. **a.** In addition to being at higher risk for urinary symptoms, data suggest that patients with central obesity do worse following surgery for LUTS/benign prostatic hyperplasia. Gacci et al. recently showed that patients with a waist circumference greater than 102 cm are less likely to symptomatically improve, specifically in regards to storage symptoms after surgery.
6. **b.** Meta-analyses have shown a running technique with long-lasting monofilament suture reduces incisional hernia rates. Additionally, a running technique taking small bites of 5 mm every 5 mm reduced the rate of incisional hernia in a recent randomized prospective clinical trial.
7. **e.** Obesity, intraoperative hypotension, steep Trendelenburg position, and lithotomy position are all associated with various forms of lower extremity compartment syndrome.
8. **e.** Reasons for increased risk of stones with obesity are likely multiple and associated with various components of metabolic syndrome. Hyperinsulinemia and resultant

insulin resistance are associated with impairments in renal ammonium production, with obese and diabetic patients shown to form more acidic urine. Low urinary pH is an important risk factor for uric acid stones, but defects in renal acid handling may also lead to hypocitraturia. Hyperinsulinemia can lead to increased urinary calcium excretion, and both hypocitraturia and hyperinsulinemia increase the risk for calcium oxalate stones.

9. **a.** In the United States, it is estimated that more than one-third of adults are obese and a staggering two-thirds of adults are at least overweight.

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17 Urologic Surgery in the Pregnant Patient

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CHAPTER OUTLINE

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KEY POINTS

1. Lithogenic urinary changes occur during pregnancy.
2. When encountering nephrolithiasis during pregnancy, conservative measures should be initially considered. If surgery is indicated and/or necessary, options include temporary drainage with ureteral stent or nephrostomy tube placement, or definitive therapy with ureteroscopy. Shock wave lithotripsy is contraindicated in pregnancy.
3. If imaging is necessary for a pregnant patient, ultrasound is a simple and inexpensive test that may provide important information. If non-diagnostic, MRI is also considered safe to use in pregnancy. The use of computerized tomography exposes both mother and unborn child to ionizing radiation; its role continues to evolve.
4. Urinary tract infections are common in pregnancy, and the most frequent bacterial cause is Enterobacter.
5. Urologic malignancies are rare in pregnancy. If they are present and warrant treatment, both open and laparoscopic approaches have been reported to be successful.

Introduction

Although surgery is a mainstay of urologic practice, in the pregnant patient it introduces a myriad of challenges due to both the presence of the developing unborn child and the requisite physiologic changes induced in the mother. The unborn child, during critical periods of rapid development, may be particularly vulnerable to adverse effects induced by urologic disease, its diagnosis, and therapeutic interventions.

Management of common urologic problems, diagnostic options, therapeutic concerns, and the potential complications that may be encountered may all therefore be significantly altered in this unique population. Herein, we shall review underlying concerns for the pregnant patient; implications for diagnosis of pertinent urologic disease; surgical considerations for open, laparoscopic, and endoscopic surgery during pregnancy; and complications specific to the pregnant population.

The Pregnant Patient

Although select urologic problems such as placenta percreta are truly unique to the pregnant patient, the most commonly encountered urologic issues in pregnant patients are, in fact, common urologic problems. The complexities of their diagnosis and management arise from issues of the pregnancy itself. Therefore it is imperative to begin with a review of concerns specific to the expectant mother.

PHYSIOLOGIC CHANGES DURING PREGNANCY

The fetus subjects the mother to a host of metabolic demands, and both temporary and evolving physical alterations, all of which may affect surgical and anesthetic concerns. Although a comprehensive review of these alterations would be prohibitive in this context, a brief review of important points is presented.

Cardiovascular Considerations

To accommodate growing requirements for oxygen and nutrition delivery, cardiac output increases by an estimated 30–50%. The vasodilating effects of prostacyclin and progesterone in addition to the low vascular resistance of the placenta cause a reduction in systemic vascular resistance, contributing to increased cardiac output. This is augmented further by increases in both heart rate and stroke volume as pregnancy progresses.[1,2]

Of particular clinical importance, this new elevated baseline cardiac output can be threatened through otherwise innocuous surgical positioning. By the second trimester, the gravid uterus emerges more prominently from the pelvis and can cause clinically significant compression of the inferior vena cava in the supine and lithotomy positions, with resultant acute drop in venous return and cardiac output. Hence, standard supine and lithotomy positions should be avoided in favor of right-sided elevation of 15–20 degrees to accomplish a left lateral tilt, thereby reducing uterine compression of the vena cava and optimally preserving cardiac output.[2]

Respiratory Considerations

Several competing alterations will affect respiratory and airway considerations in the pregnant patient. The enlarging gravid uterus ascends from the pelvis and – in concert with pregnancy-related weight gain – can exert mechanical restriction on respiration. These combined effects may result in a subsequent decline in functional residual capacity. Offsetting these mechanical concerns, early in the first trimester both respiratory rate and tidal volume increase. These changes lead to increased minute ventilation and address increasing maternal and fetal oxygen requirements.[1] A clinically pertinent effect of the increased minute ventilation is observation of a mild respiratory alkalosis, attenuated by increased renal bicarbonate secretion.[2]

Airway management is complicated by anatomic changes of pregnancy. The aforementioned weight gain of pregnancy increases the difficulty of intubation. Furthermore, edema of the oropharynx, larynx, and trachea may limit endotracheal tube placement and increase risk of bleeding and trauma related to establishment of an airway. Finally, concerns regarding decreased reliability of the gastroesophageal sphincter lead to increased risk of regurgitation and aspiration.[3]

Hematologic Considerations

Blood volume increases throughout pregnancy, ultimately increasing up to 40–50% by term.[1,4] Because the expansion of plasma outpaces the increase in red blood cell volume, there is a resultant dilutional anemia associated with pregnancy.[4] Additionally, a leukocytosis up to 15,000 WBC per microliter may be encountered during normal pregnancy, thereby potentially raising a false concern for systemic infection.[1] Finally, pregnancy is considered a hypercoagulable state due to increased fibrinogen, factor VII, VIII, X, and XII and decreased fibrinolysis, increasing the risk of thromboembolic events.[1,4,5]

Renal Considerations

There is a physiologic 30–50% increase in glomerular filtration rate during pregnancy. At the tubular level, there is a subsequent increase in urinary excretion of calcium and uric acid, which are both potential promoters of stone formation.[6] Additionally, urine pH is typically elevated, potentially related to increased urinary bicarbonate excretion to compensate for the aforementioned respiratory alkalosis. Increased excretion of citrate and thiosulfate, putative inhibitors of stone formation, is thought to offset the effects of the hypercalciuria.[7]

At the macroscopic level, mechanical compression by the gravid uterus at the level of the pelvic brim leads to dilation of the ureter and renal pelvis. This is most pronounced on the right side, with right greater than left dilation seen in 86% of imaging in one retrospective study.[8] The differential lateralization is likely related to both typical dextrorotation of the uterus as well as protective cushioning of the left ureter provided by the sigmoid colon. Besides mechanical events, hormonal effects also contribute with a suspected progesterone-mediated decrease in ureteral peristalsis.[7]

ETHICAL CONSIDERATIONS FOR UROLOGIC SURGERY DURING PREGNANCY

The previous section highlights some of the many unique physiologic changes due to pregnancy. The source underlying all of these changes is the developing child in utero. Herein also lies the critical challenge of urologic care of the pregnant patient – diagnostic and therapeutic decisions may directly affect not only the patient but also her child. Medical decision making for the pregnant patient is therefore complicated by concerns on many levels, from the patient's concerns regarding her health and the health of her child, the practitioner's attempts to maximize benefit while minimizing risks, and practical concerns regarding medico-legal risks.

In most instances, sound medical judgment aimed at taking the best care of the mother will result in taking the best care of the child. Similarly, it has been proposed that the interests of the mother will typically converge with the interests of her child.[9]

Challenging dilemmas may arise from maternal–fetal conflicts, in which either maternal actions or refusal to undergo tests or procedures directly endanger the fetus.[10] Fortunately, such conflicts do not typically arise in the context of maternal urologic disease covered here. Nevertheless, it has been recommended that due to the wide variety of motivations for such conflicts, it is critical to open a dialogue with the patient to discern the conflict, alleviate concerns, and improve the understanding of risks and benefits so as to preserve and strengthen the doctor–patient relationship.[10] The American College of Obstetrics and Gynecology (ACOG) issued a committee opinion on maternal decision making in 2005, recommending that first and foremost, the patient's autonomy in decision making should be respected. ACOG further argues against coercive legal action when these decisions fail to agree with medical recommendations, as such action would deny the mother's autonomy, potentially criminalize informed decisions, and fail to acknowledge that the medical knowledge underlying our recommendations remains imperfect.[9]

In summary, the cornerstone of medical decision making for the pregnant patient should be based on the well-informed mother understanding the relative risks and benefits of proposed interventions. These risks and benefits apply to both her and her child, recognizing the inherent limitations in medical knowledge. When conflicts arise, further counseling may divulge underlying concerns, and consultation with involved stakeholders including the patient, her family, the obstetric team, and the hospital ethics committee if needed may allow an informed and appropriate resolution.

Urologic Disease During Pregnancy

UROLITHIASIS

Kidney stones rightfully evoke significant concern for incapacitating pain. As such, they represent a source of significant anxiety. When coupled with the concerns of pregnancy, anxiety can rapidly mount for the patient, her family, and her medical providers. Symptomatic renal colic prompting admission increases the risk of preterm premature rupture of membranes and nearly doubles the risk of preterm delivery.[11,12] Unfortunately for all involved parties, urolithiasis during pregnancy is not an uncommon clinical scenario.

Epidemiology

Renal colic secondary to urolithiasis is considered the most common cause of nonobstetric hospitalization in the pregnant patient.[13] Widely varying estimates suggest that up to 1:200 women may suffer renal colic during pregnancy.[14] Gravid stone formers are most likely to be Caucasian.[11,12] Of those suffering stones during pregnancy, the majority will present in the latter half of gestation.[11,15]

The majority presenting with stones during pregnancy were not previously identified stone formers, but rather first-time stone formers.[11] Among those who are affected by urolithiasis during pregnancy, their subsequent risk of recurrent stone formation remains to be defined.

Etiology of Stone Disease During Pregnancy

A myriad of potential etiologic factors in stone formation during pregnancy have been proposed. Physiologic changes of urine chemistry increase the lithogenicity of urine during pregnancy. In particular, maternal hypercalciuria, hyperuricosuria, and elevated urine pH are all well-recognized pro-lithogenic changes during gestation.[6] The alkaline urine dramatically reduces solubility of calcium phosphate, which is reflected in the fact that approximately 75% of stones in pregnancy are calcium phosphate.[16] Despite substantial predisposition to stone formation, it is reassuring to remember that most women do not have stones during pregnancy, a fact attributed to the physiologic protection in the form of increased urinary inhibitors of stone formation including citrate.[6,7,14]

It has been hypothesized that stagnant urine in a hydronephrotic system may contribute to stone formation.[17] Thus the aforementioned "physiologic" hydronephrosis of pregnancy may be causative or coincidental to stone formation during pregnancy. As previously noted, direct external impingement upon the ureter by the enlarged uterus at the level of the iliac vessels is oft considered a primary means for mid- and proximal ureteral dilation. Ureteral dilation may additionally be a result of progesterone-induced relaxation of ureteral smooth muscle.[18] It is important to note that this dilation may obfuscate both diagnosis of ureterolithiasis and the differentiation of obstructing stone from unrelated loin pain during pregnancy.

Diagnosis of Stones During Pregnancy

The diagnosis of urolithiasis remains an imperfect art. The abdominal and loin pain of renal colic – as well as their associated nausea and emesis – are not unique to nephrolithiasis. Indeed, a large retrospective review confirmed clinical signs and symptoms alone are often inadequate to predict obstructing stones during pregnancy.[19] Even among women hospitalized for suspected acute renal colic during pregnancy, stone was confirmed in only 29%.[20] This clinical experience underscores the challenge of accurate diagnosis despite the availability of powerful diagnostic tools and enhanced imaging techniques. Attempting to predict the 29% of pregnant women with a confirmed stone diagnosis,



Figure 17.1 Ultrasound shows an obstructing right proximal ureteral stone in a pregnant patient.



Figure 17.2 Low-dose CT scan demonstrates a small left ureteral stone (arrow) in a pregnant patient.

this study found left-sided hydronephrosis >10 mm as the only significant predictor on multivariable analysis.[20] This emphasizes the confusion caused by frequent right-sided hydronephrosis and underscores the fact that the ubiquity of right-sided renal pelvic dilation in later gestation reduces the utility of ultrasound.

Nevertheless, with widespread prenatal use confirming its safety profile, ultrasound (US) remains the cornerstone of diagnostic imaging during pregnancy (Fig. 17.1). No adverse effects to mother or child have been identified. With neither ionizing radiation nor intravenous contrast administration, US is widely accepted as appropriate for use during pregnancy.

In the setting of a markedly dilated ureter, the sonographer may be able to follow the ureteral course and identify an obstructing ureteral stone, although this is the exception as opposed to the rule. Transvaginal ultrasound may allow visualization of distal ureteral stones between the transducer and the bladder when located near the ureterovesical junction. Finally, functional information may be inferred from Doppler US measurements of systolic and diastolic renal arcuate arterial blood flow. An increased renal resistive index has been utilized to successfully differentiate nonobstructive hydronephrosis of pregnancy from hydronephrosis due to ureteral obstruction.[19,21]

Although computerized tomography (CT) has clearly emerged as preferred imaging for urolithiasis in the general population, concerns regarding fetal radiation exposure continue to limit its use in pregnancy (Fig. 17.2). Advocates for CT, however, point out that its accuracy outperforms both US and magnetic resonance imaging (MRI), and radiation doses can be reduced to levels considered below the threshold for inducing fetal anomalies (Fig. 17.3).[22,23]

Management of Stone Disease in Pregnancy

An accurate diagnosis is of great importance, as symptomatic urolithiasis has been linked to maternal and fetal morbidity.[12,24] Definitive diagnosis of a ureteral stone may clarify management options but is often elusive in the parturient. In the absence of endoscopic inspection or CT demonstration, it is often impossible to confirm a ureteral stone. Therefore conservative options remain attractive in order to reduce occurrence of unnecessary surgical interventions (Fig. 17.4). As in the general population, in the absence of absolute indications to intervene one may pursue a course of active surveillance to assess for stone passage.

Medical expulsive therapy (MET) with alpha-blockers is an increasingly embraced adjunctive therapy aimed at increasing stone passage rate. To date, there has been only one study specifically reporting upon MET with tamsulosin during pregnancy. This retrospective study of 27 pregnant patients receiving tamsulosin to expedite passage of presumed ureteral stones specifically assessed perinatal outcomes.[25] In this cohort study, subjects were matched not for predictors of stone passage (e.g., stone size or stone location) but rather for risk factors for adverse neonatal outcomes (tobacco use, prematurity, or small for gestational age). Thus, stone passage was not a primary outcome and the trial was not designed to assess for this. Nevertheless, they observed a 24% increased stone passage rate in the MET group and reported that there was no statistically significant difference in perinatal outcomes. There were two cases of sudden infant death syndrome in the MET group and none in the control group, although the authors noted that there was no obvious mechanistic explanation for this, and the difference was not significant ($p = 0.11$).[25]

If conservative management is not indicated (e.g., uncontrollable pain or nausea, bilateral obstruction or unilateral obstruction of a solitary functioning kidney with subsequent worsening renal function) or if attempts at conservative management have failed, surgical intervention may be considered. These maneuvers include temporizing options including ureteral stent or nephrostomy tube placement, as well as definitive ureteroscopic stone removal. Shock wave

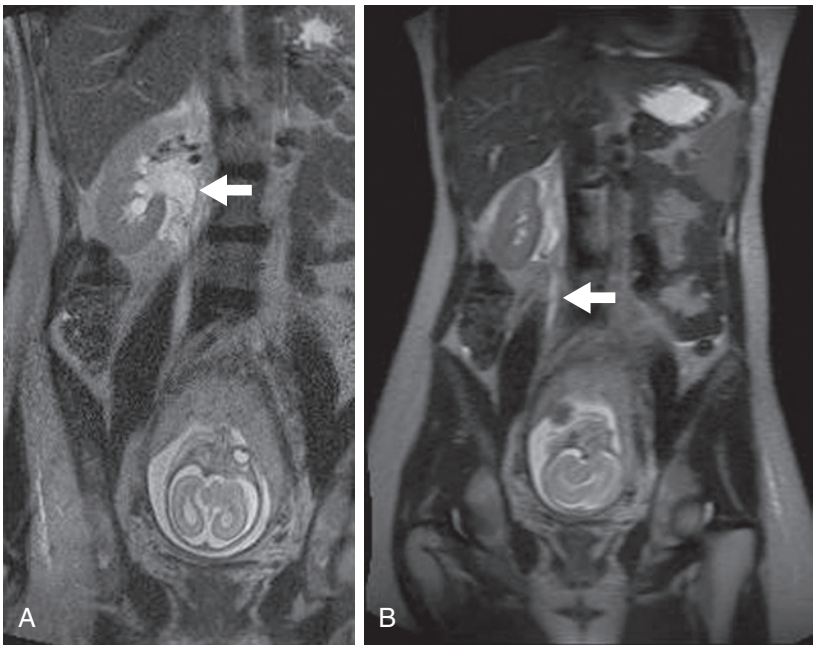


Figure 17.3 MRI of a pregnant patient with right renal colic. A, T2-weighted MRI without contrast reveals right hydronephrosis (arrow). B, Filling defect noted on HASTE MRI without contrast in the right proximal ureter later confirmed to be a 5-mm ureteral stone.

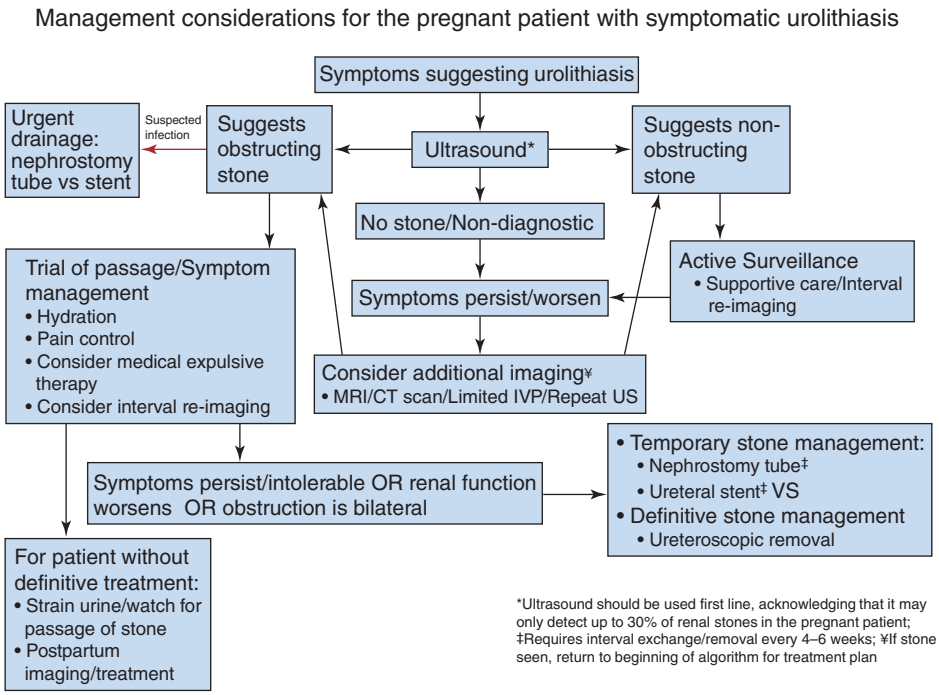


Figure 17.4 Management considerations for the pregnant patient with symptomatic urolithiasis.

lithotripsy (SWL) is contraindicated during pregnancy due to concerns of catastrophic fetal injury from shock wave injury.

COMPLICATIONS

In light of concerns of the effect of the gravid habitus on ureteroscopic maneuverability, a meta-analysis of reports of ureteroscopy during pregnancy was performed, identifying an overall 8.3% risk of endoscopic complications, Clavien grades 1–3, which did not differ from rate of endoscopic complications in the nonpregnant population.[26]

However, arguably the most noteworthy problem encountered in the surgical treatment of stones during pregnancy – accelerated stent encrustation – is not typically labeled a postoperative "complication" at all. As a result of the aforementioned physiologic changes to urine chemistry during pregnancy, aggressive accelerated stent

encrustation must be anticipated in this population. Since the earliest reports of stent use in pregnancy, rapid encrustation has been repeatedly encountered, often complicating stent removal or exchange.[27] Similarly, accelerated encrustation of nephrostomy tubes may be encountered. The best management is truly prevention, with recommendation for maintenance of excellent hydration and planned stent exchange every 6–8 weeks. Despite proactive preventative strategies, encrustation may still occur in this high-risk population. In order to reduce risk of ureteral injury or avulsion, only gentle attempts at extraction of a suspected encrusted stent should be pursued, and the attempts should be abandoned if resistance is encountered. Temporizing strategies may be employed, including placement of an adjacent, "tandem" stent to allow upper tract drainage and provide additional ureteral dilation. Additionally, one may place a nephrostomy tube to ensure drainage. In either case, the encrusted stent will require more extensive intervention in the postpartum period for extraction, including SWL of proximal encrustations, ureteroscopic lithotripsy, and/or percutaneous nephrolithotomy and extraction.[28] Additionally, others have reported ureteroscopic lithotripsy of the offending stone and stent encrustations during pregnancy to free the entombed stent and reduce the symptomatic burden as expeditiously as possible.[29]

URINARY TRACT INFECTIONS

Urinary tract infections (UTIs) remain one of the most frequently diagnosed and treated infections among women. Pregnancy increases the risk of contracting a urinary infection, the diagnosis of which is associated with adverse outcomes for both the mother and the fetus. As these infections may be encountered perioperatively and the urologist will be called upon to manage these issues, a brief review is presented. Special considerations for the pregnant woman include the role of screening for asymptomatic bacteriuria – an often otherwise benign condition in most populations – and antibiotic selection that is mindful of potential fetal effects. In the following section we review the epidemiology of urinary tract infections and their diagnosis, management, and treatment.

Epidemiology and Risk Factors of Urinary Tract Infections During Pregnancy

UTIs represent a significant public health burden; over 10 million ambulatory visits and nearly 1 million emergency department visits in the United States are attributed to UTIs annually.[30,31] Women bear the majority of these infections, and pregnancy itself is an independent risk factor for UTIs. Other risk factors for UTIs include diabetes, sexual intercourse, urologic instrumentation, history of UTIs in childhood, functional/anatomic abnormalities of the urinary tract, etc.

UTIs are the most common bacterial infection occurring during pregnancy.[32] Several normal physiologic changes occur during pregnancy that may contribute to an increased risk of UTI. These include dilation of the urinary tract, compression of the bladder by the growing uterus, urinary stasis and increased reflux, and changes to the urine itself, which may favor bacteriuria[33–35]

UTIs may be categorized anatomically into broad categories of cystitis if confined to the lower tract (including asymptomatic bacteriuria) and pyelonephritis if the UTI involves the upper urinary tract. Of particular importance, pregnancy increases the risk of cystitis progressing to pyelonephritis by 40%.[33,34]

Implications of Urinary Tract Infections and Asymptomatic Bacteriuria During Pregnancy

UTIs during pregnancy are associated with both maternal morbidity and adverse outcomes for the fetus including preterm birth and low birth weight.[34] In fact, several professional organizations recommend both screening for and treating even asymptomatic bacteriuria during pregnancy, including the U.S. Preventative Task Force (USPTF), the American College of Obstetricians and Gynecologists (ACOG), and the American Academy of Family Physicians.[34,36] Due to these recommendations screening is implemented in the vast majority of obstetric care.

Asymptomatic bacteriuria (ASB) is defined as $\geq 10^5$ colony forming units of a single bacterium per milliliter of urine in two urine samples.[37] ASB is diagnosed in approximately 5% of pregnant women.[38] Considered a benign condition for nonpregnant patients, ASB during pregnancy increases the risk of maternal pyelonephritis, preterm delivery, and low fetal birth weight.[33,39–41] A recent Cochrane review confirmed that antibiotic treatment of ASB reduced incidence of low birth weight but not preterm deliveries.[42] The USPTF recommends first trimester screening with a urine culture, although a positive urinalysis without culture should still receive proper treatment.[36] Following treatment for ASB, a follow-up culture should confirm effective treatment, with consideration for prophylactic treatment for the remainder of the pregnancy.[41]

Pyelonephritis due to ASB in pregnancy has decreased significantly in the setting of routine screening; however, it remains a significant health burden being diagnosed in 1–2% of pregnant women.[43] Pyelonephritis is a clinical diagnosis, and urine culture is the diagnostic test of choice. Blood cultures are inconsistently positive in pregnancy and official recommendations are not in place for routine blood cultures per a recent Cochrane review.[44] The majority of patients are admitted to the hospital and treated with IV fluids and empiric antibiotics until urine cultures are finalized. There is no established standard duration of treatment; however, a 7–14 day course is the most often recommended.[34] Follow-up cultures should confirm effective eradication of the infection. The bacteria most often responsible for UTIs in pregnancy are outlined in Table 17.1.

Table 17.1 Prevalence of Bacteria[33,34,115]

Pathogen	Prevalence
Enterobacteriaceae (including *E. coli*)	63–85%
Coagulase negative staphylococcus	15%
Klebsiella	8–11%
Group B streptococcus	2–10%
Staphylococcus aureus	8%

Table 17.2 Antibiotic Therapy in Pregnancy[33,34,42,43,45,46,115,116]

Antibiotic	Indication	Notable Side Effects	Comments
Amoxicillin	Asymptomatic bacteriuria (ASB)		First-line treatment
Cephalexin	ASB		First-line treatment
Aminoglycosides	Urinary tract infection (UTI), ASB	Should be avoided in the first trimester for being nephrotoxic and neurotoxic; otherwise most commonly prescribed	Streptomycin should specifically be avoided for potential damage to hearing
Fosfomycin	UTI, ASB	GI disturbances	Only requires 1 dose, data are new and limited
Nitrofurantoin	UTI, ASB	Teratogenic (?), avoid in first trimester and in the 40th week	Frequently used for lower UTIs; second-line treatment for ASB
Cephalosporins	UTI, ASB, pyelonephritis		Commonly used; avoid ceftriaxone at end of pregnancy for risk of kernicterus; any cephalosporin for pyelonephritis
Penicillin/derivatives	UTI, ASB, pyelonephritis		Commonly used; amoxicillin/clavulanic acid is second-line treatment for ASB; ampicillin + gentamicin for pyelonephritis
Sulfonamides	UTI, but generally avoided	Avoid in first trimester (?) and in the 40th week; trimethoprim requires folic acid supplementation	
Macrolides	Contraindicated except for serious or life-threatening infections resistant to other treatments	GI disturbances; teratogenic (?), increase in spontaneous abortions (?)	Conflicting data
Fluoroquinolones	Contraindicated except in symptomatic UTIs resistant to other treatments	Interferes with fetal cartilage development	
Tetracyclines	Contraindicated after 5 months	Discolored teeth in 2nd/3rd trimester	
Carbapenams	UTI, ASB		Use for patients with allergy to penicillin/cephalosporin
Aztreonam	UTI, ASB		Use only for severe allergy to beta-lactams
Glycopeptides	UTI, ASB		Limited data; consider infectious disease involvement
Miscellaneous –Daptomycin –Clindamycin –Polymyxins –Metronidazole	UTI, ASB		 –Use if benefits > risks –Review route for sexually transmitted infection treatment –Use with caution and monitor closely –Avoid topically

Management of Urinary Tract Infections During Pregnancy

It is important to consider both the mother and the fetus when selecting antibiotic therapy. As this remains a dynamic topic, consider consultation with a pharmacist and an obstetrician to assist with antibiotic selection and dosage. Local antibiograms and susceptibility should also be examined. Treatment duration generally increases based on the severity of the infection. Classic recommendations suggest 3–7 days of therapy for ASB or cystitis and up to 14 days for pyelonephritis.[34] A recent Cochrane review evaluated the duration of treatment for ASB and concluded that more data are needed and the recommendation is a standard course until these data are available.[39]

Most antimicrobials can cross the placenta; thus, care must be taken to avoid teratogens. Of note, as of June 2015 the FDA no longer uses the classic letter categorization for labeling these drugs. Instead, drugs are now classified for their phase of care including pregnancy and lactation, as well as for concerns regarding reproductive potential. Commonly used antibiotics are displayed in Table 17.2. Specific considerations are detailed in the following section.

Nitrofurantoin, often used to treat urinary infections in nonpregnant women, has been a source of controversy during pregnancy. A meta-analysis incorporating over 90,000 pregnant women receiving nitrofurantoin during the first trimester reported conflicting results. Analysis limited to cohort studies demonstrated no association of the antibiotic with major malformations in the offspring. However, analysis of the case-control studies showed a 22% increased odds for major malformations.[45] This has been refuted in other large population-based studies, and the ACOG currently does not recommend against nitrofurantoin in the first trimester in the setting if other antimicrobials are unavailable.[33]

Similar concerns exist for trimethoprim-sulfamethoxazole (TMP-SMX), and as such, many avoid this antibiotic in both the first trimester and final week of pregnancy. In addition, as a folic acid antagonist, any gravid woman taking TMP-SMX should also receive a folic acid supplement.[33]

Fosfomycin is emerging as a potentially safe and effective option during pregnancy; however, data are limited. A review of three randomized control trials of fosfomycin trometamol for both asymptomatic bacteriuria and lower UTIs showed that a single dose of fosfomycin had similar efficacy compared to cefuroxime and amoxicillin/clavulanic acid for the treatment of both conditions in pregnant women.[46]

UTIs and their treatment during pregnancy remain a dynamic topic. Poor maternal and fetal outcomes are associated with UTIs, and screening for asymptomatic bacteriuria is now the standard of care. Recommendations for specific antimicrobial agent and duration of treatment should come from a multidisciplinary team including a urologist, obstetrician, and pharmacist. Follow-up test of cure is important and women who fail to clear their infection should remain on prophylactic antibiotics for the remainder of their pregnancy.

UROLOGIC TUMORS

The diagnosis of urologic malignancy during pregnancy is a rare occurrence; published literature is limited mostly to case reports. However, when suspected it is important for the urologist to understand presentation, evaluation, and treatment of urologic cancers in the gravid patient.

Epidemiology

Of an estimated 810,170 annual cancer diagnoses in women, approximately 5% arise from the urinary tract.[47] The largest cohort study to examine the incidence of malignancy among pregnant women took place in the early 1980s and identified a rate of approximately 2.35/10,000 women.[48] Of note, other than cancer, pregnancy is the only condition in which the natural immune system is altered to allow tolerance.[49] Several studies have examined whether or not pregnancy itself is a risk factor for malignancies and have generally concluded that pregnancy does not increase the risk of malignancy.[50–52]

Renal Tumors

Renal cell carcinoma (RCC) is the most common renal tumor diagnosed in the pregnant patient.[53] Additionally angiomyolipoma, oncocytoma, and Wilm's tumor have been reported.[54–57]

Identification of a renal mass is more challenging in a gravid female patient. Hematuria may be mistaken for vaginal bleeding, hypertension may be attributed to preeclampsia, the gravid body habitus limits the physical exam, and cross-sectional imaging is less frequently employed during pregnancy.

However, once a renal mass is identified, the decision between intervention and observation is dependent on the size and stage of the mass, the suspected histopathologic subtype, and the pregnancy trimester. Treatment early in pregnancy subjects the developing fetus to risk for miscarriage or teratogenicity, whereas delaying treatment in favor of extending the pregnancy may subject the mother to risk of tumor growth or metastasis.

Successful radical nephrectomies have been reported during early pregnancy with the pregnancy continued to completion with delivery of a healthy infant.[58,59] However, it has been suggested that based on the slow growth rate of small early-staged RCCs, surgical intervention may be delayed until fetal lungs have matured at the end of the second trimester, early third trimester, or even until the postpartum period.[53] If delayed until the third trimester, one may consider concomitant nephrectomy and cesarean delivery, although in most cases the nephrectomy can be performed without having to induce labor.[60–62] A single case report described a patient who elected conservative management, although over the gestation her mass tripled in size, ultimately metastasizing and leading to death 1 year after delivery of a healthy infant.[63] Although clearly unusual, this case report underscores the need to consider the potential aggressiveness of malignancy rather than automatically deferring treatment until postpartum.

Angiomyolipomas (AMLs) are the second most common renal mass diagnosed in pregnancy.[58] Most AMLs are asymptomatic but when symptoms develop they include hematuria, flank pain, a palpable mass, and rarely hemorrhage. Size matters for these lesions; tumors >4 cm are more likely to rupture. As such, the feared complication of these tumors due to their high vascularity is spontaneous bleeding and/or hemorrhage. Treatment options in a pregnant patient are similar to those offered to the general population and include observation, embolization, or nephrectomy. Case reports have documented successful treatment of AMLs in pregnancy by all three options.[64–70]

Adrenal Tumors

Adrenal incidentalomas may be identified on ultrasound. If small in character and nonfunctioning these should be managed with observation.[53] Surveillance of these lesions has been recommended as they may represent undiagnosed pheochromocytomas.[71]

Pheochromocytoma in pregnancy has been well described. Incidence is estimated to be 1/54,000 pregnancies.[72] This was previously a morbid diagnosis carrying a fetal mortality rate >50%.[72] With advances in early diagnosis and appropriate treatment the mortality rates are nearly 0% for the mother and approximately 15% for the fetus.[54] Confounding its diagnosis are ambiguous symptoms; hypertension alone is often the only warning sign. Other classic symptoms may include headaches, dizziness, nausea and vomiting, vision changes, and palpitations. The hypertension may initially be attributed to eclampsia in a pregnant patient; however, pheochromocytoma is distinguished by its episodic hypertension presenting earlier in pregnancy and a lack of proteinuria.[73] Plasma or urine catecholamines should be obtained if clinical suspicion arises. As in the nonpregnant patient, MRI is the first-line imaging modality for evaluation and localization of suspected pheochromocytoma.[54]

Pheochromocytoma is treated with surgical excision, with attention to perioperative control of hypertension with a combination of alpha and beta blockade.[53] Similar to RCC, intervention may depend upon gestational age. Reports have noted first trimester fetal mortality rates as high as 40%.[74,75] Later in the third trimester, one may

consider resection of the tumor and simultaneous cesarean section.[76–78] Laparoscopic excision of pheochromocytoma during pregnancy has been reported with excellent outcomes.[79] Delivery without treatment of the tumor is potentially treacherous due to the increased autonomic activity for the patient. Indeed, delivery method itself is controversial for this specific neoplasm. Data show that maternal mortality is increased for vaginal delivery versus cesarean.[80]

Adrenocortical carcinomas may also present in pregnancy. These aggressive malignancies carry a poor prognosis. A case report has documented successful excision via laparoscopic adrenalectomy.[81] These adrenal tumors may be functioning or nonfunctioning; if they secrete glucocorticoids they may cause Cushing's syndrome. Alternatively, if they secrete aldosterone, they may present as preeclampsia with hypokalemia.[81] Four cases of maternal adrenal tumors resulting in fetal virilization have been reported.[82] In all four of these cases the maternal malignancy was not discovered until after delivery of the child.

Bladder Tumors

Case reports of bladder cancer in pregnancy extend back to the 1920s.[54] Often heralded by hematuria, diagnosis may be delayed due to misattribution to vaginal bleeding, reported in up to 22% of cases.[83] If concern arises for intravesical abnormality, cystoscopy can be performed safely in the pregnant patient.[48] In addition, transurethral resection can be safely performed in pregnancy acknowledging the mass effect of the uterus on the bladder.[54,83–85] Depending on the size of the mass, a staging and/or metastatic evaluation may be necessary.

Several other rare bladder tumors have been identified. Leiomyoma is a benign tumor that may present in the bladder. Four cases have been documented in pregnant patients.[86] Cystoscopy, ultrasound, MRI, and tissue biopsy are important in the work-up to differentiate from its malignant counterpart, leiomyosarcoma.[87] In pregnant patients with histologically confirmed leiomyoma, due to the benign nature of the diagnosis, surgical resection may be delayed until the postpartum period.

Ureteral Tumors

Ureteral cancer has been documented in pregnancy in two case reports.[81] More commonly, benign lesions of the ureter may present as ureteral filling defects during pregnancy, including urolithiasis and malakoplakia.

Urethral Tumors

Urethral carcinomas are another rare urologic cancer. A case report from the 1970s described a woman with a urethral adenocarcinoma that was treated with surgical excision and radiotherapy following normal vaginal delivery of her child.[88] There are several benign urethral lesions; these may increase in size during pregnancy. No emergent treatment is necessary.[89] Finally, leiomyomas of the urethra have been documented in three pregnant patients; all three were treated successfully with surgical excision.[90]

Urachal Tumors

Two case reports of urachal carcinoma diagnosed in pregnancy have been published.[91,92] One presented as abdominal pain; the other as hematuria. The first case resulted in a normal term delivery after surgical excision. The second case resulted in cystectomy along with hysterectomy in the first trimester of pregnancy due to lymph node involvement.

Imaging Considerations During Pregnancy

Although diagnostic imaging is a daily part of urologic practice, concerns regarding potential adverse fetal effects of medical radiation limit utilization of studies employing ionizing radiation during pregnancy. Radiation effects can be broadly characterized as either deterministic or stochastic effects. The latter are randomly induced events including genetic mutations and carcinogenesis, and these do not have a recognized "threshold" dose. Nevertheless, it continues to be debated whether the typical medical radiation doses associated with current diagnostic imaging increases the risk of developing childhood cancer.[93] The ACOG issued guidelines for diagnostic imaging during pregnancy and estimated that after 1–2 rad fetal radiation exposure, the risk of childhood leukemia may be elevated to 1/2000 from a baseline of 1/3000 (an absolute excess of 1/6000 children).[94]

Deterministic effects, however, are direct tissue effects from the radiation that may manifest as fetal demise (particularly if prior to implantation), or mental retardation, microcephaly, growth retardation, or congenital malformations if radiation exceeds threshold exposures. These risks are highest during the first and second trimesters when organogenesis and brain development are underway and thus most susceptible to radiation damage.[95] Nevertheless, neither fetal anomalies nor pregnancy loss was associated with radiation exposure less than 5 rad, which is well in excess of the exposure of typical diagnostic imaging.[94] In order to better assess potential fetal exposure, consultation with the institutional radiation physicist may allow appropriate dosimetry calculations.

Avoidance of ionizing radiation by using imaging techniques such as US or MRI obviates the aforementioned concerns regarding both stochastic and deterministic fetal radiation effects and the associated fetal harm. In practice, these should be considered first-line imaging options when feasible, although they are limited in particular capabilities, including diagnosis of urolithiasis. However, with guidance provided by the ACOG, patients can be counseled that medically indicated diagnostic imaging with plain films and CT may be performed within acceptable fetal exposure thresholds.

Surgical Considerations During Pregnancy

The decision to operate on the parturient must weigh the risks of untreated disease if intervention is deferred or withheld against the risks of the intervention to both the mother and her unborn child. The ACOG has issued a committee statement reassuring that no currently used anesthetic agents have teratogenic effects at standard concentrations.

Box 17.1 Recommendations for Nonobstetric Surgery During Pregnancy

Preoperative Recommendations
- Indicated surgery should not be denied based on pregnancy.[96]
- Medical decision making must respect autonomy of the mother.[9]
- Obstetric consultation should be obtained perioperatively (preoperatively if maternal condition allows).[96,100]
- Nonurgent surgery should be performed in second trimester if possible.[96]
- Surgery should be performed at an institution with obstetric and neonatal care.[96]
- Assess pre- and postoperative Doppler fetal heart rate.

Anesthetic Recommendations
- Currently used anesthetic agents have not demonstrated teratogenic effects in humans at standard concentrations.[96]
- Fetal heart rate monitoring may assist in intraoperative anesthetic assessment.
- End-tidal capnography should be utilized during laparoscopic surgery.[100]
- Patient should be positioned with right side elevated (left lateral tilt) to reduce vena caval compression.[100]

Intra- and Postoperative Surgical Recommendations
- For laparoscopic access, adjustments should be based on fundal height and prior incisions.[100]
- For laparoscopic procedures, insufflations pressures of 10–15 mm Hg can be used.[100]
- Pneumatic compression devices and early postoperative ambulation should be utilized.[100]

Box 17.2 Perioperative Fetal Monitoring

General Considerations

Have qualified individual available to interpret fetal monitoring
Have obstetric provider available if monitoring suggests need for urgent/emergent delivery

Pre-Viable Fetus

Obtain preoperative and postoperative fetal heart rate to assess fetal well-being

Viable Fetus

Perform simultaneous fetal heart rate and contraction monitoring pre- and postoperatively
Consider intraoperative fetal monitoring if:

fetus is viable
operative field physically allows monitoring
an obstetrician/provider with obstetric surgical privileges is available to intervene if fetal indications are noted
nature of operation would allow interruption of procedure for emergency delivery
patient consents to possible emergency delivery

(Adapted from ACOG Committee Opinion No. 474: nonobstetric surgery during pregnancy. Obstet Gynecol. 2011;117(2 Pt 1):420-1.)

ACOG additionally offers guidance regarding nonobstetric surgery in the pregnant patient. Advocating for both mother and child, ACOG recommends that indicated surgery should never be denied based on the pregnancy, although elective surgery should be postponed until postpartum. Nonurgent surgery should occur in the second trimester if possible, at which time both spontaneous abortion and preterm contraction are least likely.[96] These recommendations are summarized in Box 17.1.

SURGICAL POSITIONING

Due to the tendency for the dextrorotated gravid uterus to compress the inferior vena cava (IVC), left uterine displacement maximizes venous return and preserves cardiac output. This can be accomplished with left lateral decubitus positioning when possible, or left lateral tilt by elevating the right hip/flank. In procedures in which intraoperative radiographic imaging may be required, a radiolucent roll should be used for these purposes.

PERIOPERATIVE FETAL MONITORING

Guidelines for perioperative fetal monitoring are based upon fetal viability as well as the planned surgical intervention. Prior to fetal viability, fetal monitoring is limited to pre- and postoperative Doppler ascertainment of fetal heart rate. Once viability has been achieved, simultaneous fetal heart rate and contraction monitoring should be performed pre- and postoperatively. When the surgical field allows and the procedure could be safely interrupted if prompted, intraoperative fetal monitoring may be of use as signs of fetal distress could inform improved patient positioning, surgical or anesthetic maneuvers, or need for emergent delivery. A summary of fetal monitoring recommendations and conditions when intraoperative monitoring is appropriate are noted in Box 17.2.[96]

Open Versus Laparoscopic Approaches

No prospective trial has directly assessed the choice of laparoscopy versus laparotomy when surgical intervention is required during pregnancy. A review of over 2 million singleton pregnancies from the Swedish Health Registries assessed fetal outcomes after maternal intrapartum surgery. Compared to the general population, there was no difference in rate of fetal malformations among those undergoing intrapartum laparotomy (1522) or laparoscopy (2181), although they were more likely to be delivered before 37 weeks and to weigh less than 2500 g. Between the two surgical approaches there was no difference in cumulative infant survival or rate of fetal malformation.[97] Choice of surgical approach should therefore be dictated by surgeon experience and anticipated surgical exposure requirements.

In addition to the well-recognized advantages of laparoscopic surgery related to reduced pain and expedited convalescence, improved visualization has been suggested to reduce the need for uterine manipulation.[98] Initial concerns of laparoscopy included risk of inadvertent uterine injury. Uterine puncture, insufflation, and trocar placement with incidental fetoscopy resulting from laparoscopy at 19 weeks have been reported. This case report noted successful management via suture closure of the uterine puncture site, with subsequent preterm delivery at 32 weeks due to premature rupture of membranes.[99] Although the child was reported alive and well at 1 year, this highlights the importance of careful selection of laparoscopic access in this

population. Additional physiologic concerns included fetal acidosis from CO_2 absorption as well as decreased placental perfusion resulting from pneumoperitoneum. However, a comprehensive review from the Society of American Gastrointestinal Endoscopic Surgeons concluded that laparoscopic surgery could safely be performed in all trimesters of pregnancy. They noted that, although it had been recommended to maintain insufflation pressures below 12 mm Hg, insufflation to a standard 15 mm Hg has been performed without increased adverse maternal–fetal events. They therefore proposed that CO_2 insufflation between 10 mm Hg and 15 mm Hg can be safely used for laparoscopy during pregnancy, but also recommend intraoperative maternal end-tidal capnographic monitoring. Additional recommendations include adjusting abdominal access site based on fundal height, left lateral decubitus positioning to reduce caval compression, and intra- and postoperative pneumatic compression devices as well as early ambulation due to hypercoagulability during pregnancy.[100]

ENDOSCOPIC

The lithotomy position should be modified with the above-noted left lateral tilt to reduce caval compression. As endoscopic cases would allow obstetric intervention if needed, fetal monitoring should be employed when indicated. For cystoscopy and transurethral resection of bladder tumor, extrinsic impression on the bladder from the gravid uterus should be anticipated, but otherwise the procedures should not otherwise differ from the nonpregnant patient. For ureteroscopic procedures, ureteroscope access to the ureter can typically be obtained in the same fashion, with flexible ureteroscope available if required to access mid- and proximal ureteral location or to navigate ureteral tortuosity. If lithotripsy is required, the holmium:YAG laser is advocated as the preferred tool given small diameter fibers without energy transmission to mother or fetus, reduced retropulsion compared with pneumatic devices, and maximal safety margin of available lithotripsy devices.[101]

Ureteroscopy is typically performed with image guidance in the nonpregnant patient. Concerns regarding fetal radiation exposure have prompted a number of alternative strategies. Ureteroscopy solely under endoscopic visualization without image guidance has been promoted, although limited fluoroscopy was required when resistance to wire or scope passage was encountered.[101] Alternatively, sparing fluoroscopy can be used, with lead shielding placed beneath the patient's pelvis (between the C-arm x-ray tube and the uterus), or above the pelvis for easier access in which case the C-arm must be inverted.[102,103] Ultrasound guidance can also be utilized to monitor safety wire passage and maintenance within the renal pelvis, ureteroscopic position, and stent deployment, eliminating the need for fluoroscopy.[104]

Complications Related to Pregnancy

PRETERM LABOR/PRETERM DELIVERY

Preterm labor has been clearly associated with general surgical interventions during the third trimester, occurring in 82% of third trimester patients versus 26% of second trimester patients in a 2001 series from the University of California at San Francisco. No fetal loss was reported in this series, although preterm delivery occurred in 16% of those undergoing third trimester interventions.[105] A small series of 11 patients undergoing laparoscopic general surgical procedures in the third trimester demonstrated 18% incidence of preterm labor.[106] Although we lack specific reports of preterm labor from open or laparoscopic urologic procedures, one may reasonably extrapolate these risks from the general surgical literature. A multiinstitution report of 46 ureteroscopic procedures during pregnancy revealed a 10% incidence of preterm labor among patients undergoing ureteroscopy in the third trimester. One of the two was managed with tocolytics and rest, and the other progressed to preterm delivery (5%).[107] In light of such accumulated experience, the ACOG has recommended that nonurgent surgery ideally be performed in the second trimester when preterm contractions are least likely, emphasizing that any such surgery should be performed at an institution with obstetric services readily available.[96]

INVASIVE PLACENTAL ATTACHMENT

Placental chorionic villi typically attach to the endometrium; however, a recent 2015 update suggests that in 1/700 live births pathologic attachment beyond the endometrium may occur.[108] Of those with abnormal placental attachments, 81% may attach to the myometrium (placenta accreta), 12% may invade into the myometrium (placenta increta), and 7% invade through the myometrium to other pelvic structures (placenta percreta).[109] Although abnormal placental attachment can often be identified on prenatal ultrasound to prompt cesarean and possible hysterectomy, it was suspected prior to delivery in only 53%.[108,109]

The reported risk of unintentional urinary tract injury during delivery in the setting of abnormal placentation is estimated at 29%, although it may be as high as 63% when the abnormal placenta is not diagnosed antenatally but rather identified incidentally at time of surgery.[110] When urologic injury occurred, the bladder was affected most commonly (76%), followed by ureter (17%), genitourinary fistula (5%), and combined bladder and ureter (2%). In nonemergent cesarean delivery, a bladder-first approach involving formal bladder distension and dissection from the uterus before commencing with cesarean delivery has been advocated to reduce the risk of unintentional bladder injury. Additionally, this meta-analysis confirmed that preoperative temporary bilateral ureteral stent placement significantly reduced the risk of urinary tract injury (6% vs 33%, $p = 0.01$).[110]

Placenta percreta – the most severe abnormal placentation – has a reported 72% incidence of urologic complications. Due to potential invasion into the bladder, partial cystectomy was required in 44%.[111] Ultimately 4% had resultant reduced bladder capacity. Of note, despite the invasive nature of this condition, cystoscopy was not found to be useful in preoperative diagnosis in the 12 of 54 patients in whom it was performed. Gross hematuria, however, was identified in 31% and was thus advocated as a more useful tool to suggest the presence of placenta percreta and prompt further evaluation with ultrasound or

MRI. Finally, this review identified three (5.5%) maternal deaths and 14 (26%) fetal deaths associated with placenta percreta.[111]

UROLOGIC TRAUMA DURING DELIVERY

Although perineal trauma is common during vaginal delivery, surgically urgent urologic trauma is rarely associated with vaginal childbirth. However, case reports have identified at least four instances of intraperitoneal bladder rupture without concomitant uterine perforation following vaginal delivery.[112] In each case, patients presented with abdominal pain, ileus or abdominal distension, and elevated serum creatinine. The authors propose prolonged fetal pressure against the dome of the distended bladder during forceful contractions may have allowed pressure necrosis to develop. They recommend a high index of suspicion, with cystogram if needed to confirm diagnosis.

Urinary tract injury requiring urgent surgical repair is more clearly associated with cesarean delivery. The bladder is the most common site of injury, comprising 97% of urinary tract injury in the largest recent study.[113] Contemporary studies have estimated the incidence of urologic trauma injury at cesarean delivery at 0.3%.[113,114] The incidence was noted to markedly rise to 5% in the setting of urgent hysterectomy at time of cesarean.[113] Repeat cesarean more than tripled the odds of bladder injury (OR 3.82, 95% CI 1.62–8.97), although this may have been largely attributable to failed attempt at vaginal birth after cesarean.[114]

When encountered, repair of bladder lacerations and distal ureteral injuries should proceed as per standard protocols, reviewed in depth in dedicated chapters in this text.

Conclusions

Urologic disease and its management are altered by pregnancy. Physiologic and anatomic changes may affect the urinary chemical milieu, collecting system dilation, risk of stones, and infection. Furthermore, these changes and concerns regarding the rapidly developing fetus may limit our diagnostic options and their utility. Complications of childbirth may also induce urologic injury. Nevertheless, the well-informed urologist, harnessing the expertise of obstetricians, neonatologists, and anesthesiologists, may utilize current urologic surgical techniques in the service of both the patient and her child.

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Chapter 17 Questions

1. When planning surgical positioning for a pregnant patient, it is most important to consider:
   a. Dependent edema of her extremities – try to keep her hands and legs elevated
   b. Increased blood pressure relative to systemic vasodilation – ask anesthesiologist to monitor closely
   c. Urethral hypermobility
   d. Increased risk of postoperative ileus
   e. Potential compression of the inferior vena cava (IVC) by the growing uterus

2. A 34-year-old recurrent calcium oxalate stone former presents with her typical symptoms of renal colic. She mentions that she is 10 weeks pregnant. You counsel her that:
   a. No matter what size her kidney stone is, having a nidus for infection in her urinary tract increases her own risk of infection in pregnancy and the risk of harm to the fetus; she should have this endoscopically removed in the second trimester
   b. She should undergo stone protocol CT to confirm that a stone is present
   c. She is at increased risk of pyelonephritis based on her history and pregnancy; you order a urine culture and start her on prophylactic antibiotics to decrease her risk of pyelonephritis
   d. She may consider elect conservative management including hydration and oral pain medication for the time being, knowing that she has successfully passed stones in the past and that being pregnant should not interfere with this process
   e. She should have stent placement later this afternoon; you want to avoid further dilation of her urinary tract. You will place her on prophylactic antibiotics and will have the stent removed as soon as she passes the stone

3. Which of the following physiologic changes most frequently contributes to increased stone formation in pregnancy?
   a. Decreased urine pH
   b. Decreased excretion of uric acid
   c. Increased excretion of calcium
   d. Compression of the IVC
   e. Ascending bacteriuria

4. Third trimester surgical intervention as opposed to observation is most likely warranted for which of the following incidental findings?
   a. 2-cm fat-containing renal mass
   b. 5-mm mid renal calyceal stone
   c. 3.5-cm adrenal mass with normal serum catecholamines
   d. 2-cm solid renal mass
   e. 2.5-cm adrenal mass with elevated urinary catecholamines

5. The first-line imaging technique to assess for suspected urolithiasis in pregnancy is:
   a. Ultrasound
   b. Intravenous pyelogram
   c. CT scan
   d. MRI
   e. Plain abdominal film

6. On routine follow-up of urine culture results you reach out to one of your young female patients. In clinic the previous week she had a urine dipstick positive for bacteria, white blood cells, and leukocyte esterase; you started her on a standard course of Bactrim 2 days prior. Culture results show that she is growing pan-sensitive *E. coli*, and when you call to tell her to continue her course as prescribed she informs you that her symptoms have improved, she feels well, and she just had a positive pregnancy test. You:
   a. Congratulate her and advise her to continue the original prescription
   b. Tell her that due to her hypervolemic vascular state she will need fewer days of treatment but the antibiotic choice is still correct
   c. Instruct her that cephalosporins are preferred over trimethoprim and sulfa during pregnancy and switch her antibiotic accordingly
   d. Tell her that she is at increased risk of progressing to pyelonephritis and that you will thus need to admit her for intravenous antibiotic administration
   e. Tell her that the pregnancy itself likely confounded her urinalysis and that she can stop taking the antibiotics immediately; she should follow-up with her obstetrician for future urine culture

7. Which of the following is the most common organism to cause a urinary tract infection (UTI) in pregnancy?
   a. *Klebsiella*
   b. Group B strep
   c. *Pseudomonas*
   d. *E. coli*
   e. *Candida*

8. You are called to assess a 32-year-old pregnant female in the emergency room for hematuria. She is in her third trimester of pregnancy. She presented after finding "bright red blood" in the toilet after urination. Urinalysis in the ED was positive for large blood; she is otherwise stable. Your initial assessment includes:
   a. Bringing an ultrasound machine to the bedside to assess for hydronephrosis or other obvious abnormality to the urinary tract
   b. Verifying that the bleeding is from the urinary tract and not vagina; you begin with a pelvic exam assisted by an obstetrician
   c. Ordering kidney, ureter, and bladder (KUB) investigations; you are concerned that she may have nephrolithiasis as this is the most common urologic diagnosis in pregnancy. You assure her that the radiation effects from x-ray at this stage of pregnancy are minimal
   d. Sending a urine sample for culture, starting her on antibiotics, and admitting her to the hospital with a consult to the obstetrician

e. Ruling out pathology in her bladder; you perform bedside cystoscopy to rule out bladder or urethral lesion knowing that this is safe and tolerated in pregnancy

9. While all pregnant females should take a folic acid supplement, you especially ensure that they take the folate if they are being treated with which antibiotic?
   a. Penicillin
   b. Trimethoprim-sulfamethoxazole
   c. Isoniazid
   d. Cephalexin
   e. Doxycycline

10. Which of the following is the best first-line antibiotic for treating a UTI in a pregnant patient with an anaphylactic penicillin allergy?
    a. Fosfomycin
    b. Doxycycline
    c. TMP-SMX
    d. Nitrofurantoin
    e. Gentamicin

Case Study

A 26-year-old woman presents to her obstetrician with right flank pain. She is pregnant, at 17 weeks' gestation. Her pregnancy was complicated by hyperemesis gravidum limited to the first trimester; otherwise she has no significant prior medical history. She is afebrile. Screening urinalysis in the first trimester was normal. Urinalysis today reveals 18 RBCs/hpf. No leukocytes or bacteriuria are seen.

1. The most likely diagnosis is:
   a. Pyelonephritis
   b. Left renal stone
   c. Right ureteral stone
   d. Right ureteral tumor
   e. Placenta increta

2. The most reasonable initial diagnostic study is:
   a. Low-dose CT
   b. Fat-suppression MRI
   c. Doppler ultrasound with determination of renal resistive indices
   d. Diuretic renal scan
   e. Transvaginal ultrasound

3. She initially declines any further investigation after her pain is controlled. She returns to the ER 3 days later with increased flank pain, now accompanied by nausea. An ultrasound was obtained (Case Fig. 17.1). A presumptive diagnosis of right ureteral stone is made. She elects to proceed with ureteroscopy. Which is the most appropriate strategy for perioperative fetal monitoring?
   a. No fetal monitoring required at 17 weeks' gestation
   b. Obtain preoperative fetal heart rate only
   c. Obtain postoperative fetal heart rate only



Case Figure 17.1

   d. Obtain pre- and postoperative fetal heart rate
   e. Obtain intraoperative fetal monitoring with obstetrician on stand-by to perform emergency delivery if needed

Answers

1. **e.** While all choices may be considered, the most influential one on intraoperative hemodynamics would be compression of the IVC by the growing uterus. Positioning of the pregnant patient should reflect this concern.
2. **d.** Most studies suggest the majority, or at least a significant minority, of pregnant women with stones will pass them if provided with adequate hydration and symptom management. Choices a and e both involve procedures that, based on the clinical scenario provided, are not warranted this early. Choice b is incorrect because the imaging tool that should be used first in pregnancy is ultrasound, particularly in the first trimester. Choice c is incorrect as current evidence does not support the presence of a stone in this situation increasing her risk of pyelonephritis, nor would empiric antibiotics be indicated at this time.
3. **c.** Several studies have examined pathophysiology of urinary changes and stone formation in pregnancy, and the common finding is an increase in urinary excretion of calcium.
4. **e.** Choice a is suggestive of an angiomyolipoma, and surgical intervention is not recommended until the size is >4 cm. Choice b is a relatively small stone that should be offered a trial of conservative management before surgical intervention. Choice c is likely an adrenal adenoma based on the absence of elevated catecholamines and may be safely observed. Choice d is a clinical T1a renal mass that should be monitored closely and would benefit from further exploration including possible biopsy and/or partial nephrectomy. Based on its relatively small size there is no need for urgent surgical intervention during the third trimester of pregnancy.

Choice e is a functional adrenal neoplasm that puts this patient at increased risk of hemodynamic instability, especially during labor, which should be proactively treated.

5. **a.** This is the only option that puts the patient and fetus at minimal risk and is recommended as the first-line imaging tool for the pregnant patient.
6. **c.** Trimethoprim-sulfamethoxazole is less desirable in pregnancy due to potential harm to the fetus; hence a is also incorrect. Choices b, d, and e are incorrect as the pregnant state will not alter either required antibiotic duration, administration, or urinalysis results.
7. **d.** *E. coli* is the most common organism to cause a UTI regardless of pregnant state.
8. **b.** Before performing any further intervention or diagnostic technique it is most important to determine the source of bleeding. The entire work-up depends on the source of the bleeding and to avoid unnecessary procedures and potential harm to the mother/fetus, bleeding source confirmation is essential.
9. **b.** Trimethoprim-sulfamethoxazole interferes with the folic acid synthesis pathway, and supplemental folic acid should be encouraged in the pregnant patient taking this antibiotic to prevent neural tube defects.
10. **d.** Cephalosporins are considered minimal risk in pregnancy but with a history of anaphylaxis to penicillin and the 10% cross-reactivity of cephalosporins to penicillins, the next best choice with the least amount of harm to the fetus is nitrofurantoin.

CASE STUDY

1. **c.** With right flank pain, pathology on the left can be ruled out. With a urinalysis positive only for blood and not infection, the likely diagnosis is urolithiasis. While a tumor may also present with gross hematuria, it does not usually cause pain and the incidence is much lower than stones.
2. **c.** Given the history and likely diagnosis of ureteral stone, the most useful and appropriate diagnostic test in a pregnant patient is ultrasound.
3. **d.** Fetal heart rate should be assessed both before and after the procedure. Ureteroscopy has been safely performed in pregnancy, and the risk of harm to the fetus is low. Intraopertaive fetal monitoring with an obstetrician on stand-by to perform emergency delivery should be considered after fetal viability, which currently is later than 17 weeks.

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18 Management of Complications of Gender Confirmation Surgery

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CHAPTER OUTLINE

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Complications Specific to Female-to-Male Gender Confirmation Surgery
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Etiology
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Treatment
Neovaginal Prolapse
Etiology
Diagnosis
Treatment
Conclusions
Chapter 18 Questions and Answers

KEY POINTS

1. Complications in female-to-male gender confirmation surgery include urethral stricture, meatal stenosis, urethrocutaneous fistula, and persistent vaginal cavity.
2. Complications in male-to-female gender confirmation surgery are less common and include neovaginal stenosis, rectoneovaginal fistula, neovaginal prolapse, and meatal stenosis.
3. Wound healing is compromised by decreased blood flow to urethral anastomotic sites, making reconstructive procedures less likely to be successful.
4. Use of vascularized tissue flaps is an important principle in reconstruction of post–gender confirmation surgery complications.

Introduction

The prevalence of gender dysphoria is approximated to be about 355 per 100,000 persons, and 9.8 per 100,000 seek affirmation surgery.[1] Transition to the new gender involves several lifestyle, pharmaceutical, and surgical steps. While many surgeons who perform gender confirmation surgeries are plastic surgeons, it is important that urologists are involved in the preoperative, intraoperative, and postoperative care.[2] Gender confirmation surgery involves a balance of aesthetic and functional goals, and urologists are often asked to manage the urologic complications.

Complications of female-to-male (FTM) gender confirmation surgery include urethral stricture, urethrocutaneous fistula, meatal stenosis, and persistent vaginal cavity. Wound healing is impaired due to poor vascularity at the urethral anastomotic site and the tip of the neophallus. Male-to-female (MTF) gender confirmation surgery has fewer reported complications, which include neovaginal stenosis, rectoneovaginal fistula, and meatal stenosis. The urologist must be knowledgeable of the unique anatomic considerations during primary surgery as well as during management of complications. Local or regional flaps for vascular support may be needed to provide a durable outcome. This chapter reviews etiology,

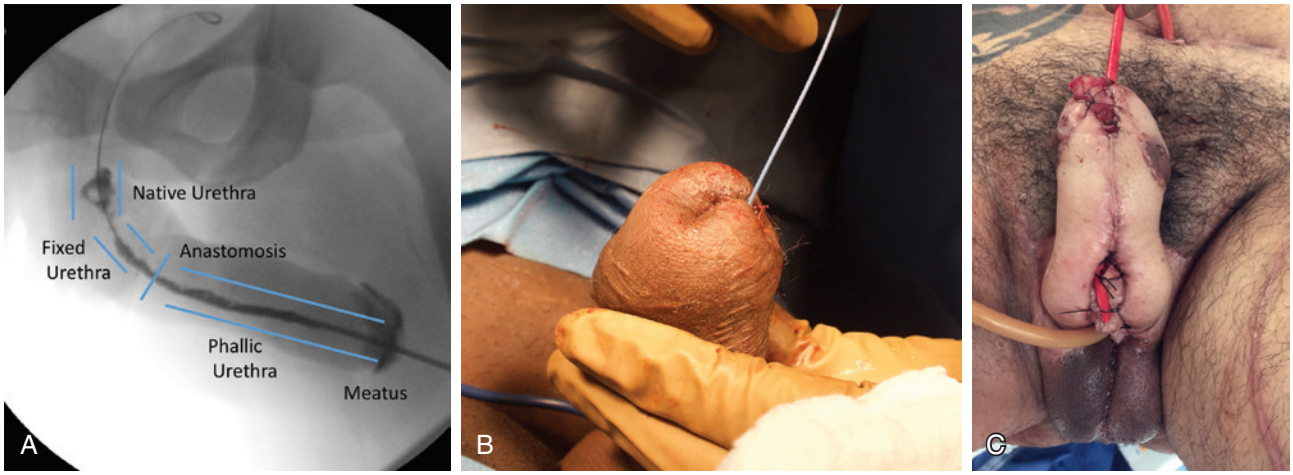


Figure 18.1 A, The urethral anatomy of the neophallus in female-to-male patients is divided into five segments: native, fixed urethra, anastomotic urethra, phallic urethra, and meatus. B, Patient with meatal stenosis after phalloplasty. C, Patient with anastomotic stenosis who underwent creation of urethrostomy at the junction of the phallic and fixed urethra.

diagnosis, and management of complications of gender confirmation surgery.

Complications Specific to Female-to-Male Gender Confirmation Surgery

Voiding from a standing position is an important goal of over 98% of patients seeking FTM gender confirmation surgery.[3] Standing to void can be achieved with the construction of a neourethra with both metoidioplasty and phalloplasty.

URETHRAL STRICTURE AND URETHROCUTANEOUS FISTULA

Etiology

Understanding the anatomy of the neophallic urethra is paramount in managing complications. The urethra is divided into five segments from proximal to distal as follows: native (female) urethra, fixed urethra, anastomotic urethra, phallic urethra, and meatus[4,5] (Fig. 18.1A). The fixed urethra is formed after lengthening of native urethra using local vaginal or labial flaps, regional flaps, and skin or mucosal grafts.[4,6] The anastomotic urethra is the portion where the fixed urethra and phallic urethra are connected. The phallic urethra is constructed using prelamination, or tube-in-tube techniques.[4,6] The anastomotic urethra is the most common site of urethral stricture.

The rate of urethral stricture after phalloplasty is reported to be from 25% to 58%.[2,7,8] Urethral stricture occurs in the anastomotic urethra in 41%, phallic urethra in 28%, meatus in 15%, fixed urethra in 13%, and multifocal in 8%.[5] The most common etiologic factor is ischemia. At the level of the meatus, contracture of neourethral tissue and neophallic skin can cause meatal stenosis (Fig. 18.1B). One series reported a mean urethral stricture length of 3.6 cm (range 0.5–15 cm).[5]

Urethrocutaneous (UC) fistula is the most common urethral complication from FTM gender confirmation surgery and is reported in 22–75% of radial forearm free flap phalloplasties.[9,10] Fistulas are usually associated with a urethral stricture and typically occur just proximal to it.[7] Most common locations are the point of urethral anastomoses between the native urethra and fixed urethra, and between the fixed urethra and phallic urethra.[7,11] The anastomotic point between the fixed urethra and phallic urethra is compromised due to attenuated vasculature of the free flap. The phallic urethra is typically narrower than the fixed urethra as a result of primary construction or contraction, which causes relative obstruction of urinary flow and resulting fistula.[7] Most UC fistulas will require surgical repair.[12]

Diagnosis

Most common symptoms for patients with urethral stricture are obstructive, including weak stream, urinary hesitancy, straining to void, and incomplete emptying. Symptoms of urethral stricture and/or UC fistula may be recurrent urinary tract infection, dysuria, or suprapubic discomfort. Review of any available operative report of the gender confirming surgery will help with understanding of the anatomic reconstruction. Physical examination may reveal palpable scar or induration at the site of stricture. Any signs of cellulitis should be noted and may be a sign of local infection, abscess, or concomitant UC fistula. Fluctuance may be noted in cases of UC fistula or abscess. Suprapubic tenderness or fullness may be signs of urinary retention that are critical to note. Urethral strictures must be repaired as long-standing obstruction may result in chronic infections, sepsis, bladder stones, and renal insufficiency. Diagnostic assessment is done using retrograde urethrogram and/or voiding cystourethrogram to assess the location and length of stricture as well as presence of UC fistula. Examination under anesthesia may be necessary given the complex anatomy. Cystoscopy should be performed in a retrograde fashion as well as antegrade if there is an existing suprapubic tube.

Treatment

If the patient has urinary retention or severe obstructive symptoms, the urine should be diverted. Foley catheter placement generally requires endoscopy and placement of a small-caliber catheter over a wire. Placement of a suprapubic tube may be helpful by resolving the acute clinical problem and as an aid in surgical planning and treatment. The suprapubic tube should be placed away from the vascular anastomosis of the neophallus, which is typically lateral to the neophallus. If the vascular anastomosis is unknown, image-guided placement or open catheter placement may be safer. Placement of a 16Fr or larger suprapubic tube facilitates performing antegrade cystoscopy for assessment of the urethral anatomy at the time of diagnostic evaluation and surgical treatment. For optimal treatment planning, review of prior surgeries and understanding of the vascular anatomy of the existing flap are paramount.

Examination under anesthesia is done with retrograde and antegrade cystoscopy to determine stricture length and location and presence of fistula. Sometimes the neourethra is narrower than the native urethra and is unable to accommodate the 16Fr flexible cystoscope. A flexible ureteroscope may be used in these cases to directly visualize the urethra. Contrast injection through the scope can be used to perform a retrograde urethrogram using fluoroscopy.

Repair of UC fistula involves closure of the fistula and reinforcement using flaps or grafts. The possibility of use of grafts or flaps while performing urethroplasty or fistula repair should be discussed with the patient. More than one stage may be needed for durable repair. Patients should be made aware of the risk of vascular damage and partial or total loss of the neophallus. If the patient does not wish to urinate from the tip of the neophallus, a perineal urethrostomy (Fig. 18.1C) is a reasonable option.

General anesthesia is used in these cases with the endotracheal tube taped to the side opposite the proposed site of buccal mucosa graft harvest. The patient is positioned in a low lithotomy position as it provides access to the genitalia, suprapubic area, and bilateral thighs for possible regional flaps. A guidewire is placed through the fistula and visualized via the cystoscope; this aids in dissection of the fistula tract. Stay sutures placed at the edges of the fistula tract help in dissection and excision of the tract. The urethral opening is closed in several nonoverlapping layers. A local or regional fasciocutaneous flap or labial fat pad flap from the neoscrotum may be used for vascular support (Figs. 18.2A and B).

If the UC fistula is associated with a urethral stricture, it should be repaired at the same time. Options for treatment of urethral stricture include direct vision internal urethrotomy (DVIU), single-stage anastomotic urethroplasty, single-stage substitution urethroplasty, staged urethroplasty, and perineal urethrostomy. Due to the lack of corpus spongiosum and compromised blood supply, urethral dilation and DVIU have an overall failure rate of 88% in this population.[8] However, for strictures of 3 cm or less, it may be a reasonable option. In one study, the success rate of first DVIU was reported to be 44%, with an additional 13% success rate after a second DVIU at a median follow-up of 51 months.[11] More than two endoscopic procedures were not successful.

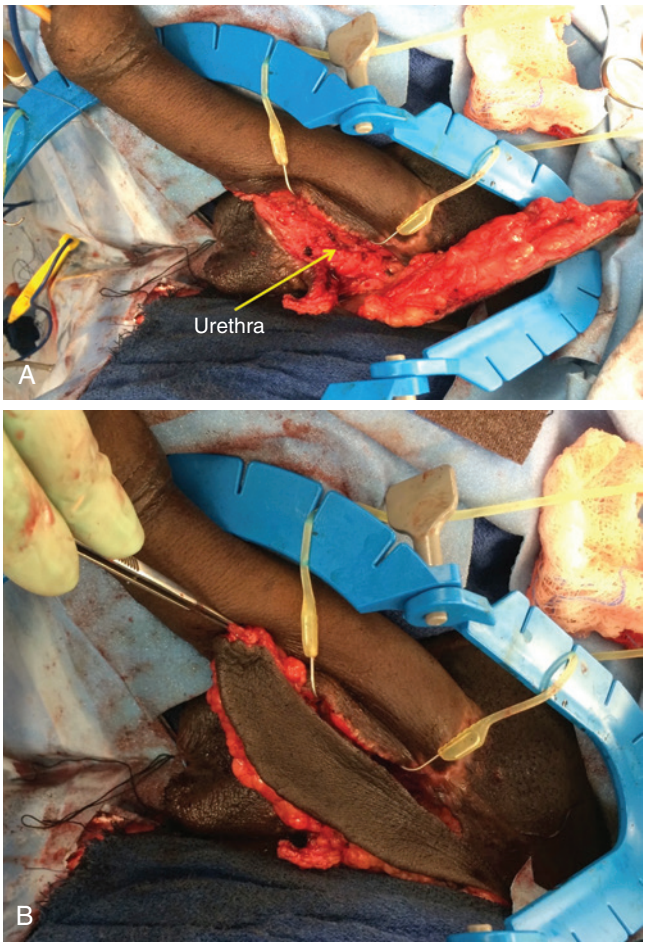


Figure 18.2 A, Fasciocutaneous flap harvested from the patient's medial thigh for ventral coverage of a urethral defect. B, Fasciocutaneous flap used for coverage and to provide support for ventral buccal mucosa graft.

One-stage anastomotic urethroplasty techniques include nontransecting urethroplasty using the Heineke-Mikulicz principle, excision and primary anastomosis, buccal mucosa graft urethroplasty, or pedicle flap urethroplasty. In a Heineke-Mikulicz nontransecting anastomotic urethroplasty, the stricture is incised vertically and closed horizontally resulting in a wider lumen.[5] Excision and primary anastomotic urethroplasty is done when the strictured segment of the urethra is less than 2–3 cm long. The stricture is excised, healthy ends spatulated, and primary anastomosis done. The success rate of excision and primary anastomotic urethroplasties has been reported to be about 57% in neophallus patients; low success rates are attributed to decreased blood supply and inability to maximally mobilize tissue.[13]

One-stage substitution urethroplasty is performed when the stricture is longer and not amenable to anastomotic repair. Several flaps or grafts have been used including fasciocutaneous flap, bladder mucosa, and buccal mucosa grafts.[8,14] A dorsal inlay approach is preferred over ventral onlay due to the better vascular bed on the dorsal surface. In traditional native dorsal inlay urethroplasty, the urethra is mobilized circumferentially. However, in neophallic urethroplasty, circumferential mobilization is not recommended as it may

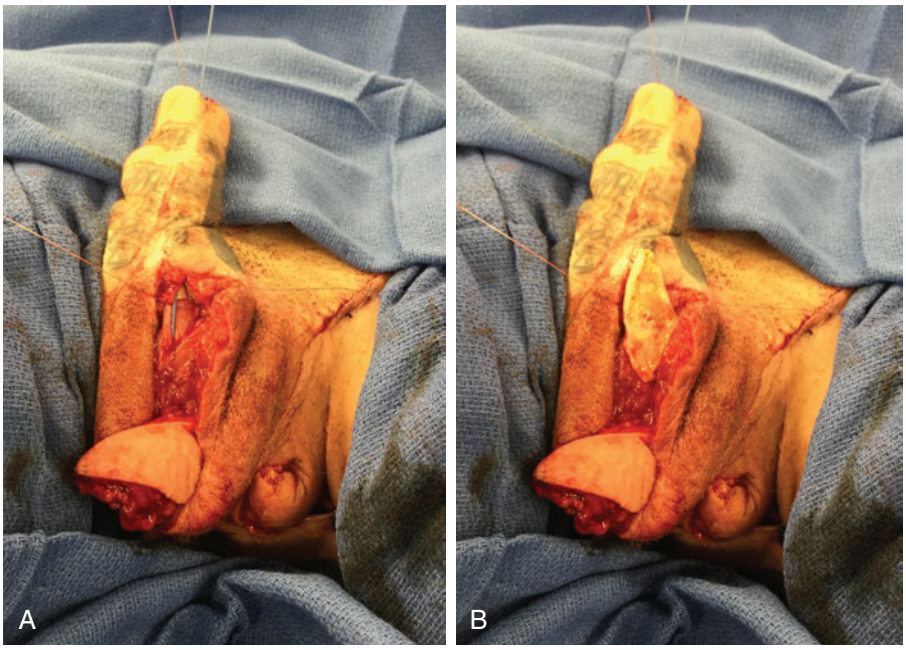


Figure 18.3 A, Neophallus with stricture of the anastomotic urethra. Urethrotomy is made ventrally. B, Buccal mucosa graft is placed ventrally, and a fasciocutaneous flap is moved over for coverage of the graft.

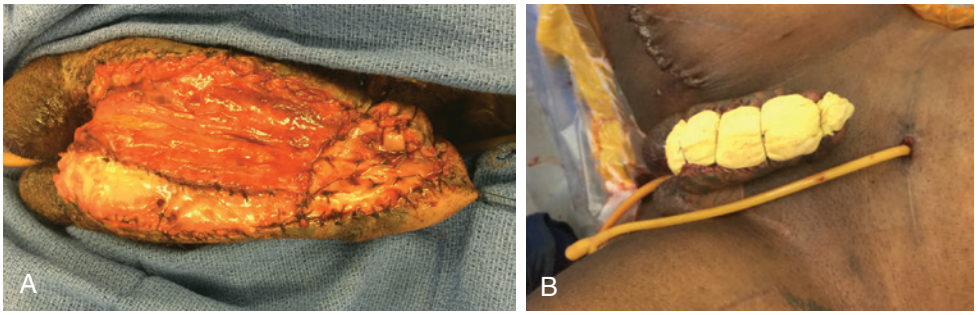


Figure 18.4 A, First-stage urethroplasty using buccal mucosa graft. B, Bolster dressing is placed over the graft for 1 week until the graft takes.

compromise the blood supply to that portion of the urethra. Instead, after the urethra is opened, a ventral urethrotomy on the dorsal surface is made and the graft placed on the dorsal surface, followed by closure of the ventral urethrotomy. In the perineal or neoscrotal area, overlapping double-face grafts can be used (Figs. 18.3A and B). Dorsal inlay is done as described. In addition, a ventral onlay graft is placed and covered with a labial fat pad from the neoscrotum or a gracilis flap. As in urethroplasty for natal males, buccal mucosa graft is the graft of choice for substitution urethroplasty for two main reasons: (1) presence of pan-laminar vascular plexus and (2) nonkeratinized epithelium used in a wet environment.

A two-stage substitution urethroplasty may be done for long or recurrent strictures. The urethra is opened ventrally. A buccal mucosa graft is placed to widen the urethral plate (Figs. 18.4A and B). Six months later, the urethra is tubularized and the neophallus is closed. This technique has the highest success rate (70%) as reported in a large neophallus urethroplasty study.[13]

Perineal urethrostomy is another option if the patient does not have a desire to urinate in a standing position. The fixed urethra is opened and approximated to the perineum to expose the native urethral meatus (see Fig. 18.1C). Despite the approach, stricture recurrence rates remain high at 60%,[5] and multiple procedures may be necessary.[7] Urinary incontinence is not an uncommon problem in these patients. This is due to urine trapping in the fixed and phallic urethra.[15] Lifelong follow-up on bladder function is important due to the high risk of bladder dysfunction given the prevalence and recurrence of urethral strictures.[2]

PERSISTENT VAGINAL CAVITY

Etiology

Many FTM patients undergo vaginectomy as a part of their gender confirmation surgery. However, if there is a distal urethral stricture, the back pressure of urine causes urine to leak from the fixed urethra into the obliterated vaginal cavity (Fig. 18.5A). Incomplete vaginectomy predisposes to this condition. A collection of fluid in this cavity leads to obstructive symptoms, urinary incontinence, and recurrent urinary tract infections.

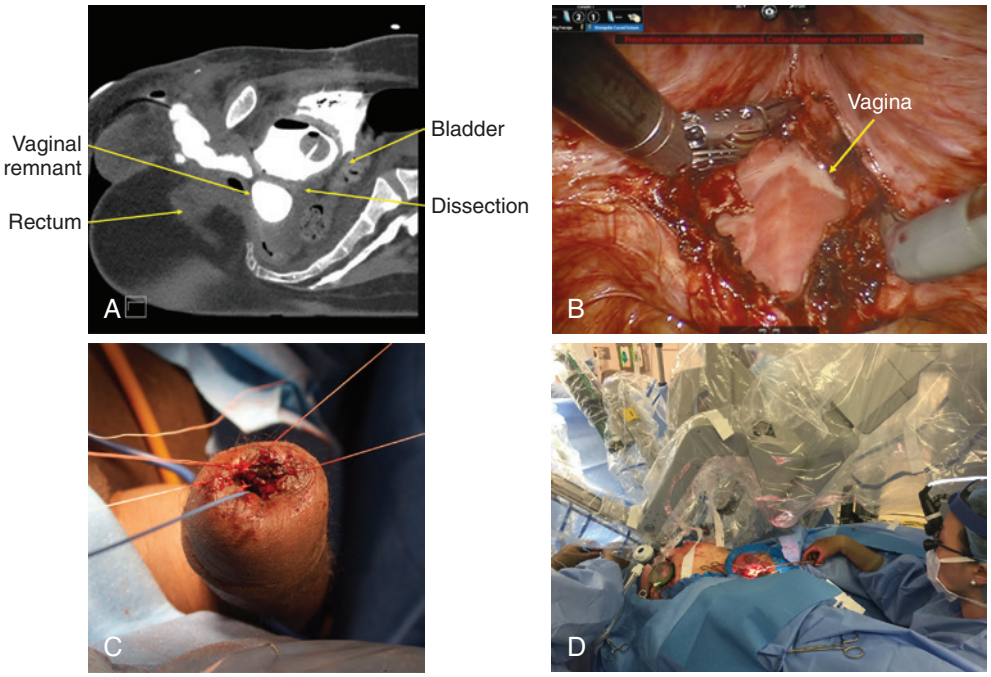


Figure 18.5 A, CT scan showing urine leaking into a cavity that is the remnant of the vagina. B, Image of robotic-assisted laparoscopic excision of the remnant vaginal cavity. C, Appearance of meatus after meatal reconstruction. D, The addition of the robotic technique to the standard perineal approach allows for intraabdominal deep pelvic dissection, helping to identify neighboring structures.

Diagnosis

If a persistent vaginal cavity is present, retrograde urethrogram and voiding cystourethrogram will reveal extravasation from the urethra and filling of a cavity. Examination under anesthesia and cystoscopy will help confirm the findings and aid in surgical planning.

Treatment

When a persistent vaginal cavity is found, it must be completely excised and the remaining space obliterated. The transabdominal robotic-assisted laparoscopic approach has been used to facilitate complete removal of the remaining vaginal epithelium (see Fig. 18.5B).

MEATAL STENOSIS OF NEOPHALLUS URETHRA

Etiology

The urethral meatus can become stenosed in about 15% of neophallus patients due to contraction of skin and the neourethra; blood flow may also be compromised at this point.[5]

Diagnosis

Diagnosis is made by physical examination. Retrograde urethrogram may be done if urethral stricture is suspected in the rest of the neourethra. Alternatively, cystoscopy is done at the time of reconstruction to assure that the rest of the urethra is normal.

Treatment

Meatal stenosis is treated with meatotomy if the rest of the urethra is uninvolved. The patient should be advised that this may result in mild hypospadias. To avoid the appearance of hypospadias, we incise the meatus in a ventral as well as dorsal fashion, excise the dense scar, and spatulate the opening (Fig. 18.5C).

Male-to-Female Gender Confirmation Surgery Complications

Surgeries for MTF gender confirmation consist of penectomy, clitoroplasty, labioplasty, orchiectomy, and vaginoplasty. While some patients undergo orchiectomy first, often all of these procedures are completed in the same surgical setting.[16] The most common technique for creating a neovagina utilizes the skin of the existing genitalia.[17] The penile skin inversion technique uses the foreskin and scrotal skin to create the vagina, and the glans penis is formed into the neoclitoris.[18] For those patients whose genital skin is not sufficient, a skin graft from the abdomen may be used to supplement.[19] Some surgeons have suggested using intestine (sigmoid, ileum, jejunum) as a substitute for genital skin. This technique's benefits include natural lubricant from the intestinal mucus secretion, no need to use hair baring skin or concern with hair regrowth, potentially a decreased need to dilate the neovagina because there are no skin grafts (scar shrinkage), and the natural caliber of the intestine.[20] However, this procedure is not without complications including stenosis at the bowel to skin anastomosis and the need to reconstruct the intestine, which can lead to risks of adhesions, bowel obstruction, bowel leak, and fistulas.[21]

The operative field for MTF surgery is the groin and perineum. The deep perineal dissection between the rectum

and the prostate can be more complicated. Experience with other procedures involving this deep perineal dissection, such as for perineal prostatectom, or posterior urethroplasty, may be useful. Additionally, depending on the patient's complication, the surgical planes may have been manipulated with resulting inflammation, scarring, and infection, making the operation more challenging.

Male-to-female procedures generally have fewer complications than FTM, likely due to the fact that less urethral reconstruction is required for this surgery. In a systematic review by Horbach et al. from a total of 12 studies, which included 1461 patients who underwent penile skin inversion, they found vaginal depth loss in 7%, meatal stenosis in 5%, neovaginal prolapse in 2%, and rectovaginal fistula in 1%.[22] The authors reported that these complications were able to be repaired with an average of one additional surgery, although follow-up was poor. Sigurjonsson et al. reviewed 205 of their MTF surgeries and found that 2% required additional surgeries for rectovaginal fistula, resection of retained corporal tissue, or meatoplasty.[23]

Most often the penile inversion vaginoplasty is performed through a single perineal incision. The surgeon uses the perineal incision to free the perineal body (central tendon) and continue the dissection, often bluntly, into a space anterior to Denonvilliers fascia and posterior to the prostate. This technique ultimately creates a vagina in the shape of a cone, which requires vaginal dilations to prevent closure.[7]

NEOVAGINAL FISTULA

Etiology

A fistula can form between the neovagina and neighboring structures resulting in rectovaginal and vesicovaginal fistula. While it has been thought that predisposing conditions like diverticular disease, ulcerative colitis, and Crohn's disease may increase the risk for intestinal fistula formation, a study of 1082 patients who underwent MTF surgery did not identify any risk factors. However, all 25 women who developed a fistula required at least one additional surgery. [24] While fistulas are uncommon, 1–2% in select series, these fistulas are caused during the neovaginal dissection, specifically at the most apical aspect.[17,21] All women required a surgical intervention. It is in this location that the surgeon encounters the prostate and posterior urethra. While one needs to be mindful of the rectum at all points in the case, this is the location where trying to define a plane posterior to the prostate is most difficult.[25] Operating deep in the perineum can be difficult, and even with modifications like rectal packing or a rectal speculum, injury to neighboring structures may be incurred.[26] An injury to the rectum that is recognized during the procedure should be repaired with a tension-free, multilayer closure followed by a low residue diet, without the need for diverting colostomy. Retrospective reviews have noted that rectovaginal fistulas are most likely caused by an unrecognized rectal injury, often with thermal or blunt dissection. These patients present with discharge from the vagina that is often brown or green and a comment of passing gas, or even stool, from the neovagina. Patients with vesicovaginal fistulas will present with urine drainage from the vagina, recurrent urinary tract infections, or pneumaturia.

Diagnosis

As stated earlier the diagnosis of a fistula can be made based on patient symptoms. If symptoms are suspected, a cystogram or a barium enema study can help to identify the fistula. In the case of vesicovaginal fistulas, cystoscopy is often not helpful because the tract may not be visible.

Treatment

All identifiable fistulas should be repaired with either primary closure or advancing a flap of local tissue (advancement flaps or pedicled flaps) for coverage.[24] Several authors have suggested a pedicled inferior gluteal artery fasciocutaneous flap because of its robust vascular supply and ability to be used throughout the perineum.[21,23,27] The location of the fistula determines if it can be repaired via a perineal approach or if it requires abdominal access. We find the use of the robotic-assisted laparoscopic approach with the interposition of omentum helpful in this regard. The decision to perform fecal diversion for a rectal fistula either with temporary colostomy or ileostomy is dependent on patient-specific characteristics and the expertise of the surgeon. Centers of excellence use these techniques when there is a very large fistula or gross stool spillage.[24,28,29]

STRICTURE OF NEOURETHRA OR MEATAL STENOSIS

Etiology

The anterior urethra (penile/bulbar) is separated from the corpora cavernosa, and the proximal urethra is then sutured circumferentially at the base of the neoclitoris. Meatal stenosis may occur due to compromised vascularity to the neomeatus. In a study of 66 patients who underwent MTF gender confirmation surgery, 5% were found to have meatal stenosis, and in a study of nearly 70 patients, 13% required surgical treatment.[27,28]

Diagnosis

The diagnosis is made based on patient symptoms. Meatal stenosis is typically characterized by a deflected urinary stream or by an increase in lower urinary symptoms including frequency, urgency, and dysuria or stranguria.[29] If symptoms are present, physical exam confirms the diagnosis.

Treatment

While a meatoplasty can be a straightforward case for most urologists, one needs to be aware that if the urethra cannot be identified, the patient will require urinary diversion with a suprapubic tube. It is prudent to have fluoroscopy or ultrasound in the operative suite during complicated urethral stricture repair. When performing the meatoplasty, one needs to be sure to have healthy urethral mucosa everted to the skin.

NEOVAGINAL STENOSIS OR ATRESIA

Etiology

When the vaginoplasty is performed through a single perineal incision and uses an inverted penile skin flap

technique, the resulting neovagina is shaped like a cone, which requires dilations to prevent closure. The timing to initiate dilations and the frequency of dilations is surgeon and center specific, but it is not uncommon for a patient to dilate 1–2 times a day. If a patient does not dilate or decreases the frequency of dilations, the neovagina may eventually contract to a diameter that causes pain with penetration. This creates a negative cycle where painful dilations are increasingly painful, which leads to a further decrease in dilations and eventual stenosis. Neovaginal stenosis can also be problematic because the tissue that lines the canal is skin and requires an opening to allow dead skin cells, sweat, and hair to leave. With neovaginal stenosis, bacteria thrive and an abscess can form.[30] Falcone et al. found neovaginal stenosis in 5.8% and atresia in 2.9% of their patients.[28]

Diagnosis

History and physical examination aid in the diagnosis of this complication. Patients relay a history of difficulty dilating as deeply as before, or a more painful dilation. Patients rarely present with vaginal atresia. Physical exam shows a narrower neovaginal canal than on previous examination. Because the narrowing usually starts in the most apical aspect of the canal, physical examination may not identify a change in depth, but the patient states that she can no longer pass the dilator as far as she did before. The contraction of the lumen may not occur in a uniform manner in a proximal to distal fashion, and there may be multiple areas of narrowing throughout the vagina.

Treatment

The first step in treatment is prevention, and if the neovagina is able to be formed as a cylinder and not a cone, not only is the need for dilation decreased but the complications of stenosis are decreased as well. We employ a transabdominal robotic-assisted laparoscopic approach to facilitate the dissection between the prostate and the rectum (similar to a robotic-assisted radical prostatectomy) and are able to connect to our perineal incision (Fig. 18.5D). This confirms an equal diameter for the entire length of the neovagina.

If patients present with stenosis a surgical procedure should be performed to relax the tension. We find that an incision perpendicular to the line of stress opens the tissue. The amount of incisions is determined in the operating room. If there is significant contracture, additional reconstructive techniques may be needed including rotational flaps. Depending on the amount of reconstruction that is performed, a vaginal stent may be placed postoperatively. Intestinal vaginoplasty is an option for complete vaginal atresia.

NEOVAGINAL PROLAPSE

Etiology

One of the most difficult and confusing aspects of the penile skin inversion vaginoplasty is how to best affix the apex of the vagina. Techniques include fixation to the sacrospinous ligament or fixture to local tissues. Authors in favor of sacrospinous ligament fixation state that it is the strongest tissue in the pelvis, and they note that this ligament has been used in vaginal vault and uterovaginal prolapse surgery for years.[31,32] Disadvantages to this procedure are risks of injury to the ureter, pudendal vessels, and nerves. Additionally, the sacrospinous ligament changes the vaginal axis to be directed to one side (right or left), making sexual intercourse difficult.[33] Because of these concerns some surgeons have suggested fixture of the neovagina at three points to local tissues, sparing the rectum, which ensures that the neovagina stays in normal orientation. A German group utilized fibrin glue for fixation of the neovagina in order to induce local scarring of the tissue.[34]

Prolapse can be understood as movement of the neovagina out of the perineal canal, which results in poor patient satisfaction with both the external aesthetic appearance and sexual intercourse. The patient may first notice prolapse after dilations as a sensation of the neovagina being pulled out of the canal.

Diagnosis

Patients will present to the surgeon's office with a complaint of their neovagina "falling out." Physical exam will demonstrate a mobile apex or side, and one will also notice some aspect of the neovagina protruding out of the canal.

Treatment

An exam under anesthesia will assist the surgeon to fully evaluate the location(s) of prolapse of the neovagina. We have been referred cases where prolapse is associated with flap necrosis. This requires significant debridement of the neovagina and additional skin grafts or flaps to repair. If the prolapse is distal, a dissection of the neovagina can be performed and tissues can be resuspended with 2-0 polydioxanone suture. If the prolapse is proximal or apical we recommend performing transabdominal exposure. In this approach, the posterior peritoneum is opened and the plane between the prostate and rectum is developed. The apex of the neovagina is suspended proximally and sutured circumferentially to ensure sufficient fixation and a normal vaginal axis.

Conclusions

Gender confirmation surgery is a challenging surgical endeavor. The expertise of urologists is important to ensure the best functional and aesthetic outcomes. The optimal approach to these complex cases is thorough preoperative planning to minimize postoperative complications. The management of postoperative complications often requires more than one surgical technique due to inflammation, scarring, infection, and compromised blood supply. The urologist is knowledgeable in the unique genital and urethral anatomy and the plastic surgeon is well versed in use of local flaps and grafts, thereby making a team approach desirable for initial gender confirmation surgery as well as management of complications.

References

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Chapter 18 Questions

1. Complications of female-to-male (FTM) gender confirmation surgery include all the following EXCEPT:
   a. Urethral stricture
   b. Urethrocutaneous fistula
   c. Persistent vaginal cavity
   d. Meatal stenosis
   e. Neophallus prolapse

2. Complications of male-to-female (MTF) gender confirmation surgery include all the following EXCEPT:
   a. Neovaginal prolapse
   b. Persistent vaginal cavity
   c. Meatal stenosis
   d. Neovaginal atresia
   e. Neovaginal fistula

3. The neophallic urethra has five parts from proximal to distal as follows:
   a. Native, anastomotic, fixed, phallic, meatal urethra
   b. Native, phallic, anastomotic, fixed, meatal urethra
   c. Native, fixed, anastomotic, phallic, meatal urethra
   d. Native, meatal, phallic, anastomotic, fixed urethra
   e. Native, anastomotic, phallic, meatal, fixed urethra

4. Which neourethral segment is most susceptible to stricture?
   a. Fixed urethra
   b. Meatus
   c. Phallic urethra
   d. Anastomotic urethra
   e. Native urethra

5. Which of the following is the most common complication of FTM gender confirmation surgery?
   a. Urethrocutaneous (UC) fistula
   b. Oral pain from harvest of buccal mucosa for neourethra
   c. Meatal stenosis
   d. Persistent vaginal cavity
   e. Neophallus atresia

6. All of the following maneuvers aid in repair of the rectovaginal or vesicovaginal fistula EXCEPT:
   a. Bowel diversion in cases of gross spillage in rectovaginal fistulas
   b. Use of local tissue advancement flaps
   c. Use of pedicle flaps
   d. Wide excision of fistula
   e. Use of omentum interposition

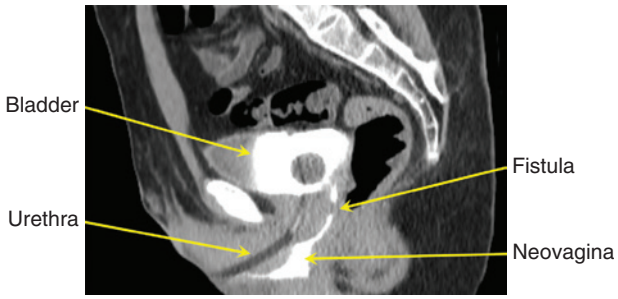
7. Which of the following is NOT a disadvantage of affixing the neovagina to the sacrospinous ligament?
   a. Risk of injury to pudendal nerves
   b. Orientation of vaginal axis to the right or left
   c. Risk of injury to ureter
   d. Risk of injury to pudendal vessels
   e. Poor aesthetic appearance

8. A FTM transgender patient presents with lower urinary tract symptoms (LUTS) and post-void dribbling per urethra. Voiding cystourethrogram confirms a patient neophallic urethra, but also identifies a collection of contrast distal to the bladder that empties on delayed films. What is the underlying pathology, and how should it be treated?
   a. Postsurgical fistula, catheter drainage
   b. Persistent vaginal canal, surgical excision
   c. Persistent vaginal canal, catheter drainage
   d. Postsurgical fistula, surgical excision
   e. No intervention needed

9. A MTF with lower urinary tract symptoms (LUTS) physical exam (transvaginal) identifies an enlarged prostate, and post-void residual is 87 mL. Cystoscopy shows an enlarged prostate with bilateral tissue ingrowth without a median lobe. Bladder has minor trabeculations with normal urethral sphincter coaptation. Initial treatment for this patient should include:
   a. GreenLight photovaporization
   b. Transurethral resection of prostate
   c. Either GreenLight photovaporization or transurethral resection of prostate
   d. Neither GreenLight photovaporization nor transurethral resection of prostate
   e. Increased fluid intake

Case Study

A 37-year-old MTF transgender patient presented with urinary incontinence 6 months after penile inversion vaginoplasty. She described dribbling from neovagina only after dilation. No stress incontinence. On physical exam, the neovagina accommodated two fingers at the introitus; however, approximately ⅔ of the way into the neovagina there was a circumferential area of scar that narrowed the lumen. She was found to have a 0.5-cm fistula between the neovagina and the bladder on cystoscopy. Vaginoscopy was performed, which confirmed a thick band of scar tissue. CT cystogram identified the fistula as well (Case Fig. 18.1). The decision was made to formally repair the urethroneovaginal fistula and perform a revision vaginoplasty with skin graft supported by a pedicled muscle flap. The fistulous tract between the neovagina and the bladder was dissected free. The bladder was closed with interrupted sutures. We started the skin graft harvest by excising skin down to rectus fascia (Case Fig. 18.2). A split-thickness skin graft was created and divided. The skin graft was modeled into a neovagina over a 20-mL syringe (Case Fig. 18.3). After dissecting out the apex of the neovagina, we inset the graft, which was supported by a rectus muscle flap (Case Fig. 18.4). A vaginal stent was fashioned using a 20-mL syringe with the plunger removed, which was then wrapped in Xeroform gauze. Abdominal skin was closed with the help of plastic surgery (Case Fig. 18.5). The Foley catheter and vaginal stent were removed on postoperative day 10 (Case Fig. 18.6). The patient was most recently seen at 10-month follow-up and was engaging in sexual activity without pain or difficulty without requiring dilations.



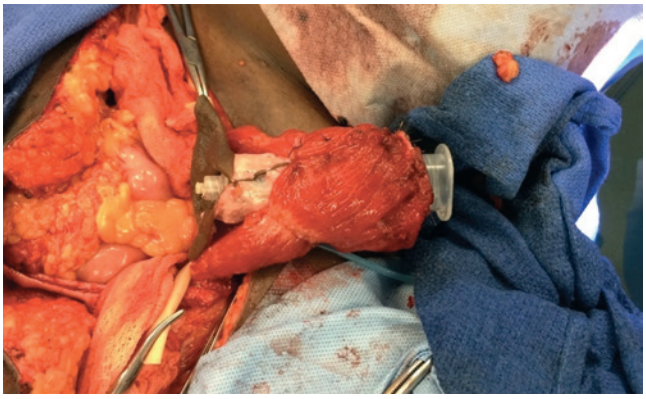
Case Figure 18.1



Case Figure 18.2



Case Figure 18.3



Case Figure 18.4



Case Figure 18.5



Case Figure 18.6

1. Which of the following flaps or grafts are NOT used to create a neovagina?
   a. Stomach mucosa
   b. Sigmoid colon mucosa
   c. Penile skin
   d. Scrotal skin
   e. Abdominal skin

2. Urinary incontinence at time of neovaginal dilation is characteristic of which diagnosis?
   a. Urinary stress incontinence from damage to the external urinary sphincter during vaginoplasty
   b. Urge incontinence due to pudendal nerve damage
   c. Fistula between urethra and neovagina
   d. Vesicovaginal fistula
   e. Mixed stress and urge incontinence

3. Which of the following treatment options is most suitable for treatment of complete neovaginal stenosis?
   a. Perpendicular incisions to release the scar
   b. Local rotational flaps
   c. Intestinal vaginoplasty
   d. Prevention of scar formation by employing a transabdominal approach
   e. Use of abdominal skin graft for repair

Answers

1. **e.** a–d are possible complications from FTM gender confirmation surgery. e is incorrect; neovaginal, not neophallus, prolapse is a possible complication in MTF gender confirmation surgery.
2. **b.** Persistent vaginal cavity is a possible complication in FTM gender confirmation surgery where incomplete resection of the vagina results in a potential cavity that is susceptible to infections and/or fistula. The other options are potential complications from MTF gender confirmation surgery.
3. **c.** The urethra is divided into five segments from proximal to distal as follows: native (female) urethra, fixed urethra, anastomotic urethra, phallic urethra, and meatus. The fixed urethra is formed after lengthening of native urethra using local vaginal or labial flaps, regional flaps, and skin or mucosal grafts. The anastomotic urethra is the portion where the fixed urethra and phallic urethra are connected. Phallic urethra is constructed using prelamination, tube-in-tube techniques, and pedicle flaps. Meatus is the most distal urethral opening.
4. **d.** Anastomotic urethra is the most common site of neourethral stricture due to lack of adequate blood supply to this portion.
5. **a.** UC fistula is the most common urethral complication from FTM gender confirmation surgery and is reported in 22–75% of radial forearm free flap phalloplasties. Oral pain (b) is a rare complication after harvest of buccal mucosa. Meatal stenosis (c) is reported in 15% of cases, and persistent vaginal cavity (d) is uncommon. A neophallus does not typically undergo atresia; a neovagina may undergo stenosis or atresia more commonly.
6. **d.** The fistula does not need to be excised widely. It may be closed primarily with use of local flaps or omentum for vascular supply as well as interposition between suture lines. Bowel diversion may be used in cases of large rectovaginal fistulas or gross spillage.
7. **e.** All of the other choices (a–d) are disadvantages of affixing the neovagina to the sacrospinous ligament. It does not result in poor aesthetic appearance; therefore that is not a potential disadvantage.
8. **b.** This patient has a persistent vaginal canal. While all FTM patients should undergo vaginectomy and an obliteration of the remaining space as part of their gender confirmation surgery, an incomplete resection will cause a pooling of urine during voiding similar to a urethral diverticulum. After voiding has completed, this collection of urine will drain out causing LUTS symptoms and recurrent urinary tract infections. If a persistent vaginal canal is identified, we advocate for a transabdominal robotic-assisted laparoscopic approach for its removal.
9. **d.** The treatment algorithm of LUTS in transgender (MTF) patients should follow standard clinical practice with a trial of medication: alpha-blockers, with or without 5-alpha-reductase inhibitors, and possibly anticholinergic medication (if the LUTS symptoms are more consistent with urgency). Endoscopic evaluation is essential to confirm urethral strictures or injury to the urethral sphincter, which can happen during dissection of the genitourinary diaphram to form the neovagina. Initial endoscopic management by either GreenLight photovaporization or transurethral resection of prostate may be too aggressive, and the patient's symptoms may be managed by medical therapy alone.

CASE STUDY

1. **a.** The rest of the options listed have been used in construction of a neovagina.
2. **d.** Leakage at time of dilation is characteristic of vesicovaginal fistula, as the dilation opens up the fistula tract. A fistula between the urethra and neovagina would result in changes in urine flow, but not urinary incontinence.
3. **c.** When extensive neovaginal stenosis is present, intestinal vaginoplasty offers a definitive repair. For mild to moderate scarring, perpendicular incisions to release the scar (a) or local rotational flaps (b) may be used. Choice d is a preventative measure that should be considered during the initial vaginoplasty surgery. Grafts (choice e) are typically not used for repair but may be considered for a smaller stenotic area if there is a fasciomuscular flap for vascular supply.

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19 Complications of Genitourinary Surgery in the Irradiated Pelvis

KARL COUTINHO and CHRIS M. GONZALEZ

CHAPTER OUTLINE

The Effects of Radiation on Wound Healing
Preoperative Evaluation and Patient Selection
Hyperbaric Oxygenation
General Intraoperative Considerations
Urethral Stricture
Rectourethral and Colovesical Fistula
Bladder Neck Contracture
Conclusions
Chapter 19 Questions and Answers

KEY POINTS

1. Radiation induced tissue ischemia, decreased tensile strength, increased scar formation, and inhibition of neovascularization all contribute to surgical complications in the previously irradiated patient.
2. Patient optimization through smoking cessation, improved nutritional status, and improved glycemic control may improve outcomes after surgery in the previously irradiated field.
3. Endoscopic management of radiation induced urethral strictures may increase the complexity of these strictures, prolong disease duration, and has a high rate of failure.
4. The keys to preventing complications in post radiation urologic surgery are multilayer, watertight, tension free closures with the interposition of healthy tissue.
5. Fecal diversion is mandatory prior to repair of post radiation rectourethral and colovesical fistulas.

Radiation therapy is an accepted primary and adjuvant treatment for a significant number of genitourinary, colorectal, and gynecologic malignancies. Within urology, external beam radiation therapy, brachytherapy, proton beam therapy, and other radiation modalities have become cornerstones in the treatment of prostate cancer, the most common nonskin-related malignancy amongst American men, with the second highest cancer-related mortality.[1] While efficacious in the treatment of prostate and other malignancies, radiation therapy can present unique and demanding challenges to the urologist due to its effects on surrounding genitourinary structures. In a retrospective series analyzing 964 patients, Dean and Lytton found a 2.5% incidence of urologic complications resultant from pelvic radiation after a 5- to 10-year follow-up.[2] In another retrospective study of 10,709 patients who received pelvic radiation for gynecologic malignancies, Maier and colleagues found a 1.24% incidence of severe urologic complications of which radiation cystitis (49%), urinary fistula (26%), and ureteral stenosis (25%) were most common. Most of these patients (88%) required a urologic procedure for which complication rates were significantly higher when compared to nonirradiated patients.[3]

This chapter describes the etiology, diagnosis, and perioperative management of common radiation-related complications of the lower urinary tract.

The Effects of Radiation on Wound Healing

To understand the complications of surgery in the previously irradiated field, it is important to discuss the pathophysiologic effect of radiation on tissue and wound healing. The process of wound healing begins at the moment of injury and is classically divided into four phases: hemostasis, inflammation, proliferation, and maturation.[4] Each stage is predictable in its onset and mediated by the interactions of numerous cell-signaling molecules in a sequential cascade. This complex process of healing can be interrupted directly or indirectly at several stages by the effects of radiation. The direct effects of radiation on cell proteins and DNA leads to inhibition of cell replication, or cell death through instability or apoptosis. The indirect effects of radiation involve the excitation of intracellular molecules and the generation of free radicals that in turn damage genetic material, signaling mechanisms, and other cell components.

Radiation's effect on the cell signaling molecules in the wound-healing cascade has been studied in a large and growing field of research. Radiation-induced alterations in the expression of several cell-signaling molecules have been documented in both human and animal models. These include interferon-γ (IFN-γ), transforming growth factor

beta (TGFβ), vascular endothelial growth factor (VEGF), nitric oxide (NO), and tumor necrosis factor (TNF), as well as a variety of interleukins (IL) and matrix metalloproteinases (MMPs). The downstream effects of these alterations include disorganization of extracellular matrices; impairment of neovascularization and cell migration; and disordered collagen deposition leading to compromised blood supply, tensile strength, and the inability to recover from subsequent insults,[5–8] all contributing to surgical complications in the irradiated field. The severity of these effects is dependent on a variety of factors, most importantly the total dose of radiation, dose per fraction, and surface area of the treatment field.[4,9,10] Individual sensitivity to radiation may also vary and has been shown to play a part in determining the extent of radiation-induced injury.[11–13]

Preoperative Evaluation and Patient Selection

An important step to improve surgical outcomes in the previously irradiated patient is minimization of risk factors for poor wound healing such as tobacco use, hyperglycemia, and poor nutritional status. Whenever possible these issues should be addressed preoperatively through patient counseling, referrals to specialists, or changes in medication.

Diabetic control can be assessed preoperatively though serum hemoglobin A1C (HbA1c) testing. Retrospective studies have identified increased length of stay and worsened surgical outcomes in diabetic patients with HbA1c levels at 7% or greater.[14–17] While the implications of rapid correction of HbA1c have been debated, and no widely accepted preoperative "cutoff" guidelines exist, diabetic control should be assessed via serum glucose and HbA1c testing in order to facilitate preoperative counseling regarding outcomes, especially in the previously irradiated patient. If the situation permits, referrals to diabetic nutritionists and endocrinologists should be pursued in order to maximize glycemic control preceding surgery.

Combustible tobacco use is a significant inhibitor of wound healing, necessitating cessation when at all possible prior to surgery. Smoking decreases oxygen levels in tissue, impairs cell migration, decreases neovascularization, and increases the presence of inflammatory mediators. This has been shown to result in increased rates of wound dehiscence, increased healing time,[18] worse cosmetic outcomes of surgical scars,[19] reduced skin graft take,[20] increased rates of postsurgical infections,[21] and increased overall complication rates.[22] With tenuous tissue characteristics already present in irradiated tissue fields, the impact of smoking greatly increases the risk for poor outcomes following surgery. Sørensen and colleagues have shown that smoking cessation results in restoration of tissue oxygenation and blood flow within 1 day, and restoration of inflammatory cell functions within 4 weeks.[23] This short timeline of reversal makes smoking cessation counseling a necessary step in the perioperative management of not just previously irradiated, but all urologic patients.[24]

Optimization of nutritional status is an important step in achieving good surgical outcomes. Several studies show improvements in surgical outcomes and complication rates with better preoperative nutritional status as measured by serum albumin and validated tools such as the Nutritional Risk Classification, or Nutritional Risk Screening 2002.[25–28] Enteric supplementation is universally preferred in patients who can tolerate it. However, studies evaluating the impact of short course (~10-day) preoperative enteric supplementation on postoperative complications and outcomes have yielded conflicting results.[29,30] Similarly, meta-analyses of studies on preoperative parenteral nutrition were also indeterminate as to its actual impact on outcomes.[31–33] Still, the European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines suggest that there may be a benefit to preoperative short-term (7- to 10-day) parenteral nutrition prior to surgery in a select group of severely malnourished patients unable to sustain enteral supplementation. The American Society for Clinical Nutrition and Metabolism (ASPEN) recommends nutritional supplementation only when enteral intake is impaired. Although consensus is lacking, an assessment of nutritional status through albumin measurement, combined with patient characteristics through a nutritional screening tool, would allow the urologist to properly advise patients on their individual risk of complications related to poor nutrition.

Hyperbaric Oxygenation

Hyperbaric oxygenation (HBO) represents a potential perioperative therapy for carefully selected patients with a history of radiation. HBO has been used for over three decades in the treatment of post-radiation complications of head and neck cancers[34,35] and has been well explored in the treatment of radiation cystitis.[36] A recent meta-analysis on the use of HBO for a variety of surgical procedures, including pelvic surgery, suggests that preoperative HBO may reduce wound breakdown, infection, fistula formation, and flap loss after surgery in the irradiated patient.[37] Mechanisms of action discussed in this meta-analysis include stimulation of angiogenesis, reduction of fibrosis, improved tissue oxygenation, and stimulation of stem cells and stem cell derivatives.

In a small series of patients with a history of complications from pelvic radiation for gynecologic, bladder, and spinal malignancies, Pomeroy and colleagues showed a reduction in radiation-related post-surgical complications in patients treated with HBO prior to planned pelvic surgery.[38] Patients underwent 30 HBO "dive" sessions at 2.0 atmospheres prior to bladder augmentation, urinary diversion, or palliative resection of recurrent pelvic tumor, followed by 10 sessions postoperatively. The authors noted fewer radiation-related complications in these patients, which they attributed to the stimulation of angiogenesis and promotion of wound healing. Although limited by its size, this study indicates a possible role for pre- and postsurgical HBO therapy in reducing surgical complications in the previously irradiated patient.

General Intraoperative Considerations

The hallmarks of the irradiated surgical field are a paucity of reliable tissue planes, an abundance of scar tissue, and

tissue atrophy. Preoperative stents, catheters, or wires (through fistula tracts or small strictures) are useful in the identification of relevant genitourinary structures while operating in irradiated fields; the authors recommend their placement whenever possible. Additionally, the inhibition of collagen content remodeling seen with radiation leads to a decrease in tissue tensile strength.[39] As a result, maneuvers such as "sweeping" and other blunt dissection techniques may result in tissue damage rather than a separation of planes. Sharp dissection under visualization is key throughout any case in an irradiated field, with care taken to establish and reestablish anatomic landmarks during the procedure. Bony landmarks are most reliable, as they do not change post-radiation; however, palpation may be difficult in some areas due to patient size and fibrotic scar tissue.

General principles for wound closure in an irradiated field are shown in Box 19.1. A watertight closure of the urinary tract in multiple layers should be completed with irradiated tissue. The integrity of such closures should be tested via irrigation intraoperatively and reinforced if necessary. In situations where tissue integrity of the genitourinary tract is questionable, as in most post-radiation cases, the diversion of urine through urethral or suprapubic catheterization, or percutaneous nephrostomy drainage is prudent in order to maintain a dry anastomosis and prevent fistula formation and wound breakdown. Fecal diversion is mandatory in a post-radiation enteric fistula to the urinary tract, and should be performed prior to urologic repair. In cases of urinary diversion, a stepwise approach to "un-diversion" is advisable with replacement of catheters if urine leak is suspected. Often this process can take several weeks or months due to the slow healing nature of irradiated tissue. While algorithms have been described for periodic assessment and un-diversion,[40] there are no established guidelines for fecal un-diversion. Most studies, however, advocate waiting at least 3–6 months post successful repair.[41,42] In cases of rectal sphincter involvement or damage, consideration of a permanent diverting colostomy should be considered. Following fistula repair, fecal un-diversion should be attempted last, after urinary un-diversion and a period of observation to ensure proper closure of the urinary tract. Premature fecal un-diversion holds the risk of contamination, infection, and potential wound breakdown in the already tenuous irradiated field.

The interposition of nonradiated, healthy tissue into the irradiated field can be challenging and may be determined by the surgical approach. With perineal surgery, access to gracilis flaps, labial flaps, tunica vaginalis, or dartos tissue flaps should be considered. During transabdominal procedures the omentum is a reliable source of healthy tissue for interposition. Proper mobilization of a tension-free flap based on the right gastroepiploic artery allows for extension of the omentum as far inferiorly as the proximal urethra and should be utilized liberally in transabdominal procedures. Kulkarni and colleagues have described laparoscopic mobilization of omentum during the perineal approach for posterior urethroplasty.[43] In this series of patients undergoing repair of complex and re-do pelvic-fracture–associated urethral injury, omentum was mobilized inferiorly through a peritoneal incision and placed between the prostate and rectum. However, due to the close proximity of the rectum and the difficulty of dissection in this area, the use of omentum through this approach should be considered a last resort if no other healthy tissue is available.

Wound closure of the abdominal cavity and perineum is as crucial to operative success as any other factor in post-radiation surgery. A large retrospective analysis of 160 previously irradiated patients undergoing abdominoperineal resection of the rectum (APR) with perineal wound closure found that the rate of major wound complications more than doubled in patients with a history of pelvic radiation as compared to patients who did not receive radiation preoperatively (41% vs 19%, $p < 0.02$).[44] The rate of fascial dehiscence with major abdominal surgery for both irradiated and nonirradiated patients ranges from 1% to 6%,[45,46] with an average mortality of 25%.[47] While retrospective reviews have not associated prior radiation with an increased risk of abdominal dehiscence,[48] there is a lack of data in this patient population. The use of retention sutures to prevent postoperative abdominal-wall fascial dehiscence is controversial and has not been proven to provide benefit at the cost of greater patient discomfort and local complications at the suture site.[49] Abdominal binders may reduce pain postoperatively;[50] however, similar to the use of retention sutures, there is a lack of evidence to support the use of abdominal binders to prevent seroma formation or reduce the rates of wound dehiscence. Further information on abdominal wound closure is covered in detail elsewhere in this book.

Box 19.1 General Surgical Principles in the Irradiated Pelvis

1. Watertight closure of the urinary system
2. Interposition of healthy tissue
3. Multilayer closure of the GU tract
4. Tension-free wound closure
5. Appropriate diversion of the fecal and urine streams for fistulas

Urethral Stricture

Santucci and colleagues estimated the incidence of male urethral stricture disease to be about 0.6% of the general population.[51] Radiation therapy, through any modality, has been shown to increase this incidence. Among those who have had pelvic radiation, the incidence of urethral stricture increases from 1.7% to as high as 5.2% for those receiving combination brachytherapy and EBRT.[52,53] Overall, urethral strictures are most commonly associated with EBRT.[54] The pathophysiology of urethral stricture in the post-radiation patient is related to chronic oxidative stress subsequently leading to vascular damage, ischemia, and poor wound healing of the surrounding tissue.[55] The resulting fibrosis of the corpus spongiosum leads to urethral stricture formation, which can present several years following the completion of therapy, and is typically found in the bulbar urethra extending to the prostate.[56] Endoscopic management of these strictures, regardless of location and the type of intervention, carries a high rate of recurrence, upward of 50–60%.[56,57] Additionally, repeat endoscopic procedures

have been shown to increase the complexity and length of a stricture.[58]

The first step in management of the post pelvic radiation urethral stricture is the diagnosis of stricture length and location via a retrograde urethrogram (RUG). A suprapubic tube may be necessary in patients with obliterative urethral strictures. In these situations, antegrade cystoscopy and concomitant retrograde urethrogram can define a stricture's length and location (Fig. 19.1).

Urethroplasty in the irradiated pelvis can be a challenge due to tissue fibrosis and obliterated surgical planes of dissection. Utilization of a suprapubic cystostomy assists the surgeon in identifying the proximal extent of the urethral stricture which extends to the prostatic urethra during perineal dissection. It is advisable to start dissection distally, where the urethra is less affected by pelvic radiation, continuing proximally once the proper tissue planes are identified. As previously described, the typical bulbomembranous location of most radiation-induced strictures requires proximal dissection to the prostatic urethra.[55,59] Once proximal dissection is achieved, resection of necrotic tissue at or to the prostate may be necessary in order to expose healthy mucosa for an anastomosis. Surgical instruments such as a pituitary rongeur have been utilized to accomplish prostatic resection.[60] The Capio device (Boston Scientific, Massachusetts) has proven useful in the authors' experience to deliver anastomotic sutures to the prostatic urethra when conventional suture placement is not feasible. This device, often used in female prolapse surgery, allows passage and suture capture in limited space and operates at oblique angles, which makes it ideal to capture prostatic or bladder mucosa through the perineum.

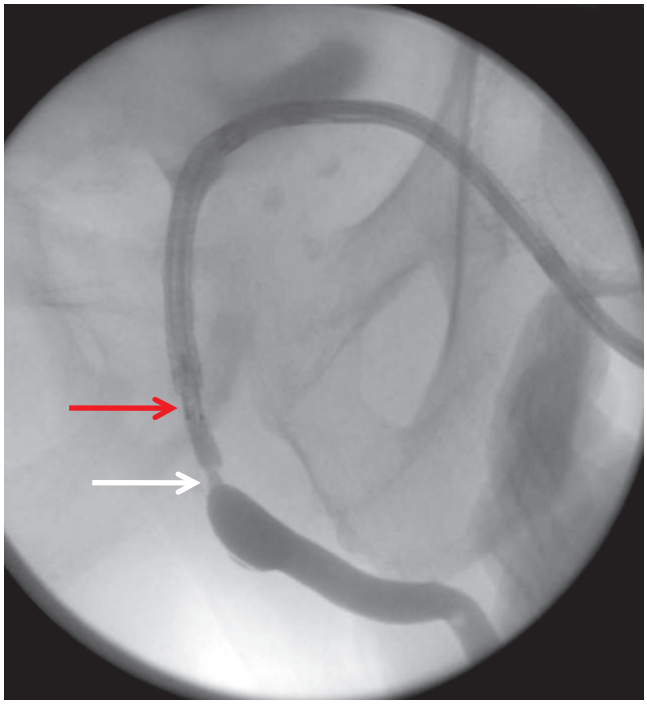


Figure 19.1 Simultaneous antegrade and retrograde urethrogram ("up-and-down-ogram") using a flexible cystoscopy though the suprapubic tract. The white arrow denotes stricture and the red arrow denotes the cystoscope.

Grafts or fasciocutaneous flaps may be utilized for the repair of lengthy post-radiation urethral strictures, with good results seen in small series.[61] However, graft uptake in the irradiated perineum can be somewhat tenuous due to the often fibrotic and avascular resection bed. Buccal mucosa appears to be the most ideal graft in these situations due to its thin lamina, good vascularization, and remote location away from the irradiated field. For excision and primary anastomosis (EPA), surgical maneuvers such as splitting of the corpora, re-routing the urethra around the corpora, or resection of the pubic bone have been described, but are rarely necessary once adequate mobilization of the proximal and distal urethra have been achieved.

Data evaluating the efficacy of urethroplasty specifically in post-radiation patients are limited to retrospective case series with limited follow-up. Nonetheless, acceptable outcomes following urethroplasty for post-radiation urethral strictures have been reported.[54,55,61] In one multi-institutional retrospective series of 72 men with radiation-induced strictures EPA was the predominate technique used. The average stricture length was 2.4 cm in this cohort, with most strictures located in the bulbar or bulbomembranous urethra.[60] Overall success was 70% in these men at an average of 2.9 years' follow-up. Stricture recurrence in this series was associated with stricture length >2 cm and treatment center.[54,60] Substitution urethroplasty in this series was reported on six patients; four patients with a graft and two with a flap. Mean stricture length in these men was 4.3 cm. Stricture recurrence was reported in one of these patients after 7 months.

In cases of relatively short (<3 cm) recurrent bulbar urethral strictures in the irradiated pelvis, repeat EPA should be considered in order to excise as much surrounding ischemic spongiosum as possible. Aggressive mobilization of the urethra is necessary and is feasible in the proximal bulbar urethra. In lengthier stricture recurrences, pedicled fasciocutaneous genital skin flaps may be more successful than graft substitution due to the added benefit of the flap retaining its own blood supply as compared to a graft placement into an irradiated host bed. Overall in irradiated patients, several studies have demonstrated successful outcomes using perineal, scrotal, or penile skin as both flaps and grafts, as well as gracilis muscle as a carrier for grafts.[60,62]

Urinary incontinence is a potential complication following bulbomembranous urethroplasty in the irradiated pelvis. In one series the onset of new postoperative urinary incontinence was 36–50%; however, 20% of these patients (3/15) experienced spontaneous resolution of their incontinence 4 weeks after surgery.[60] If incontinence does not resolve, an artificial urethral sphincter can be offered.[54,60,61]

As in nonirradiated patients, it does not appear that erectile function is significantly altered following urethroplasty in men with previous pelvic radiation.[60]

Rectourethral and Colovesical Fistula

The development of rectourethral (RUFs) or colovesical fistulas (CVFs) are troublesome complications seen in the post-radiation prostate cancer patients. While historically

associated with surgical injuries during rectal or prostate surgery, an increasing number of patients have been reported with radiation-induced fistula. The incidence of RUF after radiation ranges from 0.2%[63] to as high as 2.9%[64] in patients receiving multimodality radiation therapy for prostate cancer. Lane and colleagues reported that since 1998, 50% of reported cases of RUF involved pelvic radiation (mainly EBRT, brachytherapy, or combination), as opposed to 3.8% prior to 1998.[41] No matter what the approach, the repair of these fistulas can be tedious and difficult. Surgical planning and a multidisciplinary approach are necessary for a successful outcome.

Common signs and symptoms of RUF and CVF include fecaluria, urine per rectum, recurrent urinary tract infection (UTI), pelvic pain, and hematuria.[40] Patients with prior radiation have been reported to have a higher incidence of wound infection, transfusion requirements, and increased time to fecal un-diversion as compared to nonirradiated patients.[65] Identification and localization of RUF and CVF involve history, physical exam, imaging, and endoscopy. Physical examination includes evaluation of the perineum for cutaneous tracts, as well as digital rectal exam to palpate the fistulous tract and determine its distance from the anal verge. The fistula tract will generally feel firm and fibrotic on rectal exam. Computed tomography with triple infusion (oral, intravenous, and rectal contrast), followed by cystoscopy with retrograde urethrogram and cystogram, is recommended to localize the fistula and plan the reconstructive approach (Fig. 19.2). Cystoscopy has a high sensitivity (80–100%) for fistula diagnosis within the bladder and allows for measurement of the size and location of the fistula in relation to the ureteral orifice, prostate, bladder neck, and external urinary sphincter.[66] Small fistula tracts may not be visible, but can present as bullous edema of the urothelium, seen with raised erythematous edges (Fig. 19.3). Larger fistula can present on cystoscopy with an easily identifiable tract into the rectum (Fig. 19.4). Biopsy of the fistula tract during cystoscopy is recommended if there is a suspicion of malignancy. Anoscopy or colonoscopy is also useful in surgical planning and should be performed by appropriate specialists in order to identify the enteric fistula location and size.

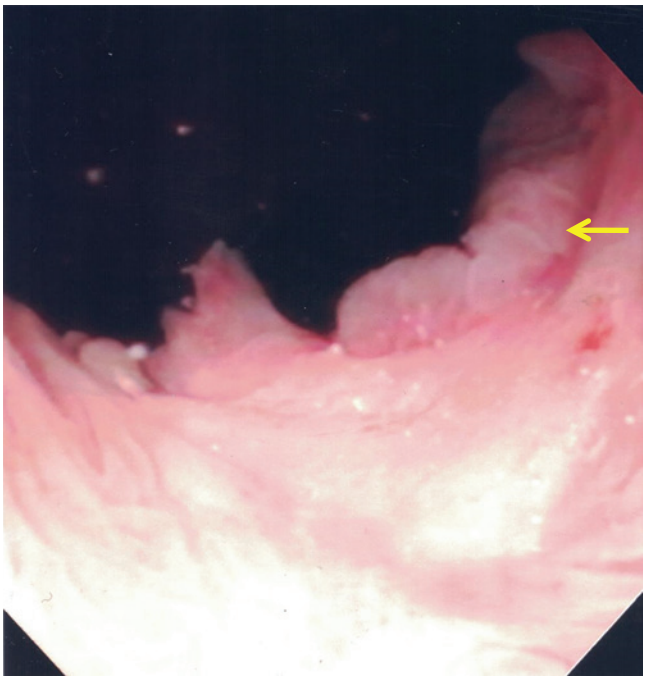


Figure 19.3 A rectourethral fistula seen on cystoscopy with raised, bullous, mucosal edges and erythema (arrow).

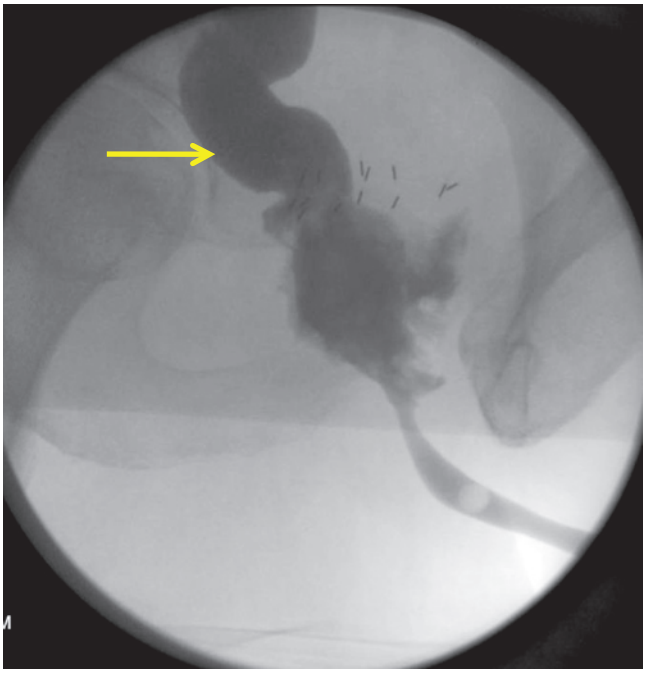


Figure 19.2 Appearance of a rectourethral fistula on retrograde urethrogram. Contrast is seen filling the rectum (arrow), with brachytherapy seeds noted in the prostate.

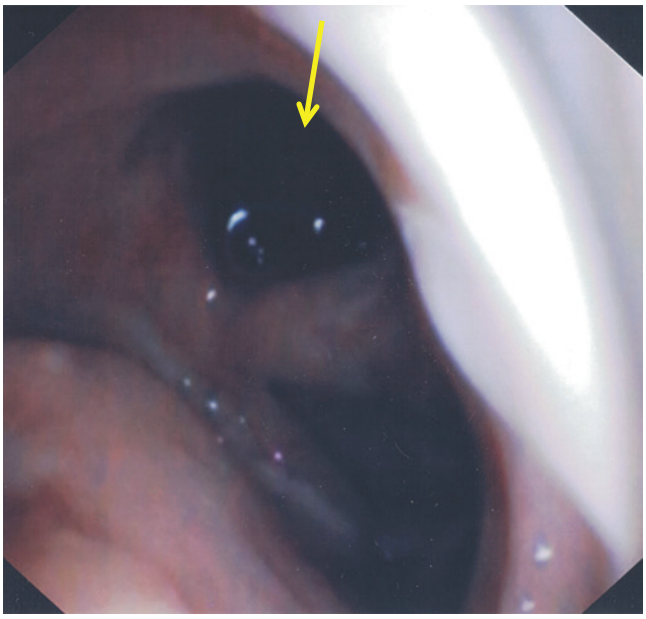


Figure 19.4 A large rectourethral fistula noted on cystoscopy with a clear view of the rectal mucosa (arrow) seen from the lumen of the urethra.

In the previously irradiated patient, fecal diversion in conjunction with urinary diversion is mandatory. Temporary suprapubic urinary diversion is useful for two reasons: It allows the diversion of urine away from the fistula, and it allows "urethral rest" in order to evaluate the patient for concurrent urethral stricture formation. One study puts the incidence of concurrent urethral strictures at 30% in patients with RUF.[42] Although conservative management with both urinary and fecal diversion has been successful in some patients with small, less fibrotic fistulas,[67] it is rarely successful in our experience with post-radiation RUF or CVF. Furthermore, HBO therapy has not been shown to reduce the need for surgical management.[68] Assessment of a patient's functional and health status is key, as operative management tends to be more complex with a longer postoperative recovery in the irradiated patient.[65] The location of these fistulas can range from the bladder to the bulbar urethra, highlighting the need for both cystoscopy and radiologic imaging to fully assess the extent of disease. Preoperative ureteral stenting can be considered prior to repair of fistulas that appear to be in close proximity to the ureteral orifices, especially in post-prostatectomy patients.

Options for management of radiation-induced RUF and CVF depend on the location, size, and etiology of the fistula. Due to the rarity of these fistulas, combined with their heterogeneity in type and patient characteristics, there are little data on the standard approach to surgical management. Prior to incision, placement of a small catheter or guidewire may aid in identification of the fistula tract.[69] Surgical approaches to the fistula include trans-sphincteric, transanal, transperineal, or transabdominal. General surgical principles necessary to achieve the best outcomes for a fistula in a previously irradiated pelvis are shown in Box 19.2. While some studies have noted worse outcomes of fistula repair in post-radiation or cryotherapy patients,[70,71] Whick and colleague's meta-analysis of all available RUF patients undergoing repair showed comparative success rates (90%) for irradiated and nonirradiated patients alike, with the exception of patients who underwent transanal repair. A transabdominal approach was most commonly utilized in previously irradiated patients undergoing RUF repair (74.4%). However, direct comparison of groups in this case series was difficult as operative approaches and postoperative permanent fecal and urinary diversion rates were significantly different for irradiated and nonirradiated patients. Additionally, 25% and 42.5% of irradiated patients were unable to have their fecal and urinary diversions reversed after RUF repair, respectively, as compared to only 4% of nonirradiated patients.[72] Similar to urethral stricture repair, urinary incontinence was not uncommon after RUF repair (up to 71% in one cohort of both irradiated and nonirradiated patients).[73] For those patients with moderate-to-severe urinary incontinence following RUF repair, successful treatment with AUS implantation has been reported.[73,74]

The transphincteric approach was developed circa 1960 by English surgeon Aubrey York Mason, for whom it is now commonly named. Utilizing this approach, the patient is placed in a prone jackknife position (Fig. 19.5). An incision is made from the anal verge to the coccyx, allowing dissection through subcutaneous tissue with exposure of the posterior rectal wall. The posterior rectal wall is opened, exposing the anterior rectal wall and fistula tract. This dissection requires careful division and reapproximation of the rectal sphincter.[75] With proper technique, the risk of postoperative fecal incontinence is negligible.[76,77] The York Mason approach was described for RUF repair in 1969 by both Kilpatrick and Mason.[78] This approach is beneficial in providing excellent visualization of proximal RUF and CVF fistulas near the bladder neck. Closure can be accomplished in three layers (urothelium, interposed mucosa, and rectal wall), and this approach is generally well tolerated with relatively limited recovery time. However, interposition of healthy tissue between the urinary tract and rectum is limited to tissue immediately adjacent to the fistula, which may also be damaged from prior radiation. Interposition of distant healthy tissue such as a gracilis flap requires a separate perineal incision, which increases operative morbidity. While good results have been shown for many iatrogenic RUFs, the York Mason approach has a higher rate of recurrence with radiation-induced strictures (4/7 patients recurred in one study) and larger diameter fistulas and is, therefore, not recommended for complex post-radiation RUF, re-do RUF repair, or post-radiation fistulas greater than 2 cm.[79]

The transanal approach to RUF repair involves dilation and circular retraction of the anus, allowing exposure of the fistula tract through the dilated anal canal. The fistula tract can then be excised and a flap of rectal mucosa is closed over the tract. The transanal approach is well tolerated and has the benefit of avoiding disruption of the rectal sphincter.[80,81] However, exposure is difficult for proximal

Box 19.2 Surgical Principles for Rectourethral Fistula Repair in the Irradiated Pelvis

1. Prior fecal and urinary diversion
2. Identification of the fistula tract through adequate exposure
3. Complete excision of the fistula tract and pathologic analysis of tissue
4. Interposition of healthy tissue
5. Multilayered closure of the fecal and urinary streams



Figure 19.5 Prone jackknife positioning.

fistulas, and this technique does not allow for healthy tissue interposition. Meta-analysis of outcomes after fistula repair demonstrated a higher rate of surgical repair failure for the transanal approach when compared to other approaches.[72] Therefore complex or irradiated RUF using a transanal approach should be avoided.

The perineal approach is well represented in literature, especially amongst urologists. Two recent studies utilizing the transperineal approach for RUF amongst patients with previous pelvic radiation and ablative therapy demonstrated successful fistula closure rates of 76.9% and 100% at mean follow-up times of 15.6 and 11.4 months, respectively. In both studies all patents underwent fecal diversion preoperatively, and most (38% and 100% in each study, respectively) underwent tissue interposition during the perineal approach. In these studies, the most common interposed tissue was gracilis muscle (9/20 patients combined), followed by dartos (2/20), and a rectus muscle flap (1/20).[42,73]

During the transperineal approach, the patient can be placed in either a lithotomy or prone jackknife position. A U-shaped incision is made in the perineum, and dissection is carried proximally between the urethra and rectum until the fistula tract is encountered and excised and the surrounding rectal and urethral mucosa closed. Exposure of rectal fistulas involving the proximal urethra or bladder may be difficult with this approach, especially in obese patients. Management of the urethral defect is through primary closure or, for larger urethral defects, graft onlay.[73] Benefits of the perineal approach include the familiar dissection for the urologist as well as the ability to interpose a variety of tissue sources between the bowel and urinary tract suture lines including gracilis muscle, genital skin, or tunica vaginalis. Dartos muscle interposition during the perineal approach is possible; however, a higher rate of failure has been reported, most likely due to the fact that the dartos tissue also resides within the irradiated field.[82] Gracilis muscle interposition has been utilized most successfully in post-radiation patients with the perineal approach as this tissue is robust, well vascularized, and located outside of common radiation field limits.[71,73] The use of synthetic grafts such as AlloDerm has also been described with successful outcomes in radiotherapy- and cryotherapy-induced fistulas.[83]

The transabdominal approach is recommended for more anatomically proximal fistulas or when simultaneous bowel resection, prostatectomy, or other related procedures may be necessary. While more invasive than other approaches, a lower midline incision allows for excellent exposure of CVF after opening the anterior bladder wall. Access to the omentum allows for ample tissue interposition during repair. In meta-analysis, the transabdominal approach provided the best rates of success for radiation- or ablative-therapy-induced RUF repair, with a failure rate of only 6.9% (2/29 patients).[72]

Bladder Neck Contracture

Bladder neck contracture (BNC) is a complication most commonly reported in the post–radical prostatectomy patient; however, BNC after radiation therapy is notably different from posttraumatic or postsurgical etiologies. Often these contractures can present years after treatment and are thought to be a result of microvascular injury causing progressive, chronic ischemia, fibrosis, and necrosis.[84–87] Multimodal therapy for prostate cancer, which includes any form of radiation, has been associated with higher rates of BNC and a higher risk of failure of endoscopic treatment.[88–90] Patient characteristics, such as active cigarette smoking, hypertension, diabetes, and coronary artery disease, have also been linked to a higher rate of BNC development after prostatectomy in cohorts that included patients with prior pelvic radiation, emphasizing the importance of patient counseling.[91,92]

After clinical signs and symptoms present, such as difficulty with urination and high post-void residual, the diagnosis of BNC can be confirmed via cystoscopy or RUG (Fig. 19.6). In-office urethral dilation has been described with postprostatectomy BNC, with the best outcomes in patients compliant with intermittent self-catheterization protocols to maintain bladder neck patency.[93] However, these outcomes are reported in cohorts where the etiology of BNC is previous transurethral resection of prostate or radical prostatectomy without adjuvant radiation. There are little data to determine if post-radiation strictures respond similarly.

Various modalities such as the cutting loop, hot knife, cold knife, and laser have all been described for post prostatectomy and post-radiation BNC, with varying degrees of efficacy.[94–97] Recent data have demonstrated good outcomes using balloon dilatation followed by deep lateral bladder neck incisions with a hot knife at the 3- and 9-o'clock positions into perivesical fat.[92] The majority of patients in this study (78%) had failed previous attempts at endoscopic management before attempting bladder neck incision. Over a 5-year period, 50 patients underwent deep lateral incisions of their BNC with a 72% success rate at a mean follow-up of 12.9 months. Success of the procedure was defined as passage of a flexible cystoscope without the need for further procedures. Again, this cohort was primarily



Figure 19.6 Retrograde urethrogram of a bladder neck contracture after radical retropubic prostatectomy.

patients who developed BNC after radical prostatectomy (35/50, 70%) or TURP (13/50, 26%), with a limited number of patients who underwent prostatectomy with adjuvant radiotherapy (2/50, 4%). Nonetheless this approach can be considered for endoscopic management of a BNC in the previously irradiated pelvis.

Intralesional injection of mitomycin C after cold knife bladder neck incision has been reported in the nonirradiated, post–radical prostatectomy, recurrent-BNC population with a 72% success rate after a single treatment at median follow-up of 12 months.[98] However, in a multi-institutional trial of 55 patients, of which 25% had prior radiation therapy for prostate cancer, success after a single treatment was lower at 58% at a median follow-up of 9 months.[99] In this same study, four patients were reported to have experienced serious adverse effects (Clavien IIIb) from mitomycin including osteitis pubis, bladder necrosis, and RUF. Of note, three out of these four patients had prior radiation therapy, and all three irradiated patients required eventual cystectomy and urinary diversion. Similar adverse effects including bladder and perivesical fat necrosis have been described in other mitomycin trials.[100] Steroid injection following holmium laser BNC incision has been described with success rates of 83% at a mean follow-up of 24 months in a cohort of post–radical prostatectomy patients, most of whom (79%) had recurrent BNC.[101]

More study is needed to determine the role of steroid or mitomycin injection following BNC endoscopic incision.

Open bladder neck reconstruction has been reported, almost exclusively in the nonirradiated, postprostatectomy population.[102,103] The surgical approach is determined by the patient's anatomy and extent of fibrosis. The key to a successful repair is adequate exposure of the bladder neck during reconstruction. Exposure has been described through perineal, abdominal, transpubic, or a combination of approaches depending on the extent of the contracture and other individual patient characteristics. In one series of four patients with postprostatectomy BNC reconstruction, two patients underwent pubectomy with bladder neck reconstruction completed with a penile skin onlay flap in one, and reconstruction of an anterior bladder neck tube in another. Transpubic exposure allowed for rectus muscle flap and omental interposition to cover each repair, respectfully. A third patient, the only one to have received previous radiation, underwent a perineal approach due to a long stricture involving the anterior urethra. In this case, a penile fasciocutaneous flap was used to complete a combined onlay urethroplasty with bladder neck repair. The last patient underwent a combined abdominal and perineal approach with excision and end-to-end primary anastomosis. At a mean of 33.8 months, all patients had a patent urethra, although one required a single dilatation after surgery. All patients were incontinent after their procedure, and two underwent successful placement of a staged AUS.[103]

A combined abdominal and perineal approach was described in a series of six patients with obliterated BNC after multiple attempts at endoscopic intervention.[102] In this series, abdominal and perineal approaches were used to mobilize the bladder neck distally and the bulbomembranous urethra proximally for a tension-free end-to-end anastomosis. All patients received simultaneous AUS placement, and three patients received bladder augmentation with ileum. Five patients were voiding adequately at a mean follow-up of 24 months, with one patient requiring intermittent self-catheterization. Almost all patients were continent at last follow-up, with one patient requiring one pad daily. Only one patient had erosion of the AUS cuff, requiring replacement. Of note was that none of these patients had previous radiation exposure. In the authors' experience men with recalcitrant BNC following radical prostatectomy, adjuvant XRT, and failed endoscopic management (Fig. 19.7) are best approached with a simultaneous abdominal and perineal approach. It is important to assess bladder capacity prior to reconstruction in these patients as those with a capacity less than 200 mL will require bladder augmentation as well, or urinary diversion. In this combined approach the pubic bone is resected through the transabdominal approach for exposure to the bladder neck and to allow for anastomosis of the mobilized urethra to the bladder neck (Fig. 19.8A, B). Staged AUS for urinary incontinence is planned 4–6 months following this procedure, as all are incontinent of urine. In men with recalcitrant BNC following radiation treatment to the prostate, a retropubic approach to the bladder neck provides adequate exposure for excision of the BNC and creation of an anterior bladder wall advancement flap. Preoperative evaluation must demonstrate a bladder capacity of at least 250–300 mL in these patients for development of an appropriately sized anterior bladder wall advancement flap.

In patients with recalcitrant BNC not amenable to bladder neck reconstruction, bladder neck closure with concurrent creation of a catheterizable stoma with bladder augmentation has been described with acceptable outcomes.[88] Urinary diversion with or without cystectomy represents another option for patients who are not candidates or who do not desire bladder neck reconstruction.

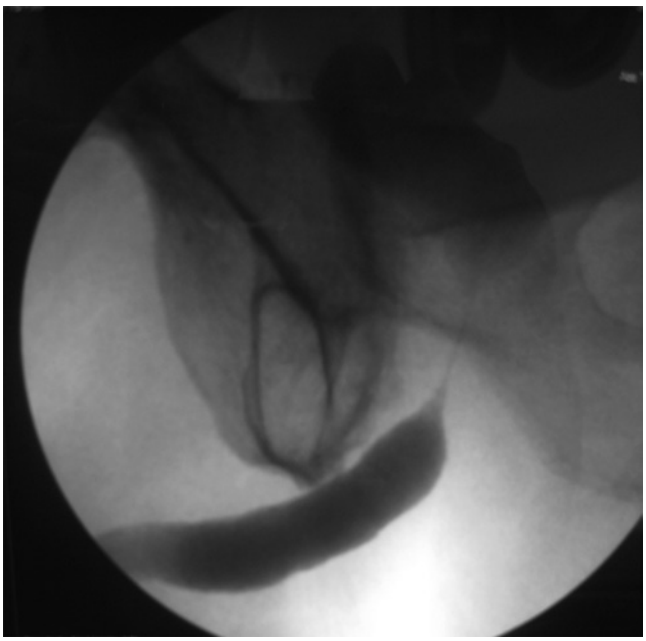


Figure 19.7 Retrograde urethrogram of a recalcitrant bladder neck contracture extending to the bulbar urethra following radical prostatectomy and adjuvant external beam radiation.

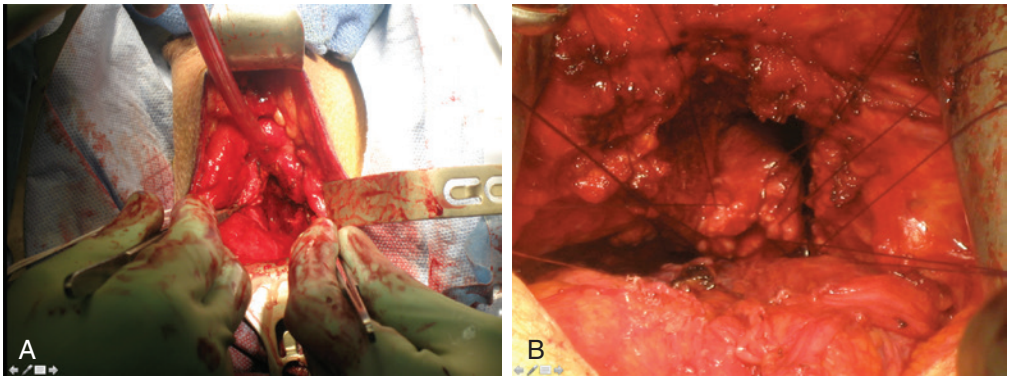


Figure 19.8 A, Mobilization of the urethra and splitting of the corpora cavernosal bodies to reach the bladder. B, Anastomosis of the mobilized urethra to the bladder after pubectomy.

Conclusions

Surgery in the previously irradiated pelvis presents a unique challenge for urologists. In addition to dealing with the many complications of radiation damage to the tissues, the risk of surgery is considerably higher even in the absence of discernible complications. When performing routine procedures on the prostate, bladder, and lower ureters following radiation, one must be attentive to the condition of the tissues. Even when normal in appearance, it is likely that vascularity, pliability, and healing are compromised, thus resulting in a higher likelihood of leak, stricture, and need for reoperation. Identification of healthy tissue, minimization of excessive mobilization (thereby disrupting already fragile vascularity), and interposition of healthy tissues are all essential operative strategies for achieving good outcomes. In utilizing specialized techniques, good outcomes can clearly be achieved. In dealing with strictures, fistulas, or badly damaged bladders as a consequence of radiation injury, one must recognize that there is a high likelihood of treatment failure with conservative or minimal surgical approaches. Surgical reconstruction with a low threshold for diversion in cases of refractory disease processes, may be prudent.

References

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Chapter 19 Questions

1. Perioperative hyperbaric oxygenation has been shown to do which of the following in the previously irradiated patient?
   a. Reduce fibrosis
   b. Stimulate stem cell and stem cell derivatives
   c. Improve tissue oxygenation
   d. Reduce wound breakdown
   e. All of the above

2. Which of the following is TRUE regarding perioperative nutritional support?
   a. Parenteral supplementation is preferred over enteral nutrition in patients with poor nutrition status
   b. Serum sodium and glucose levels are the most useful blood tests to determine nutritional status
   c. The American Society for Clinical Nutrition and Metabolism (ASPEN) recommends nutritional supplementation only when enteral intake is impaired
   d. Nutritional status has not been shown to have any impact on wound healing
   e. Nutritional screen tools have not been validated for clinical use in screening preoperative patients

3. Place these steps of the wound healing cascade in the correct order:
   a. Hemostasis, maturation, inflammation, and proliferation
   b. Proliferation, inflammation, hemostasis, and maturation
   c. Hemostasis, inflammation, proliferation, and maturation
   d. Inflammation, hemostasis, maturation, and proliferation
   e. Hemostasis, proliferation, inflammation, and maturation

4. Radiation has all of the following effects on treated tissue, EXCEPT:
   a. Disorganization of extracellular matrices
   b. Increased cell migration
   c. Reduction in tissue tensile strength
   d. Impairment of neovascularization
   e. Disordered collagen deposition

5. The perineal approach to rectourethral fistula repair allows easy access to all of the following tissues useful for interposition EXCEPT:
   a. Gracilis muscle
   b. Tunica vaginalis
   c. Dartos muscle
   d. Omentum
   e. Penile skin

6. Which surgical approach to rectourethral fistula repair is NOT recommended in the previously irradiated patient?
   a. Transanal approach
   b. Abdominal approach
   c. York Mason approach
   d. a and c only
   e. a and b only

7. Which of the following is TRUE regarding the surgical treatment of post-radiation fistula?
   a. Pelvic MRI is the most sensitive test for the diagnosis of rectourethral fistula
   b. The incidence of concurrent urethral stricture in patients with rectourethral fistulas is as high as 30%
   c. Cystoscopy has poor sensitivity in the diagnosis of colovesical fistula
   d. Un-diversion of the GI tract should be attempted before urinary un-diversion in the post–rectourethral fistula repair patient
   e. On digital rectal exam, a fistula tract will feel spongy and soft

8. Which of the following is TRUE regarding open bladder neck reconstruction of a recalcitrant bladder neck contracture in a man following radical prostatectomy and adjuvant radiation therapy?
   a. Bladder neck reconstruction should be the first step in managing post-radiation bladder neck contractures
   b. Bladder capacity must be 200 mL or less in order to develop a sufficient bladder advancement flap for bladder neck reconstruction
   c. Bladder neck reconstruction is almost always associated with postoperative urinary incontinence
   d. Exposure of the anterior urethra is the key step in a successful open bladder neck reconstruction
   e. AUS placement is not recommended after open bladder neck reconstruction due to the risk of erosion

9. Which of the following is FALSE regarding endoscopic management of post-radiation urethral strictures?
   a. Endoscopic management of these strictures carries a recurrence rate upward of 50–60%
   b. Repeat endoscopic procedures have been shown to reduce the complexity of strictures and shorten disease duration
   c. Cystoscopic evaluation and retrograde urethrogram are the recommended initial diagnostic studies to determine stricture location and length
   d. Antegrade cystoscopy and injection of contrast through a suprapubic tract is useful in determining the length of obliterative urethral strictures
   e. All of the above

10. Which of the following complications is least associated with urethroplasty in the post-radiation patient?
    a. Urinary tract infection
    b. New onset urinary incontinence
    c. New onset erectile dysfunction
    d. Hematuria
    e. Dysuria

11. The most common location for post-radiation urethral stricture formation is at the:
    a. Bulbomembranous urethra
    b. Bladder neck
    c. Fossa navicularis
    d. Penile urethra
    e. Prostatic urethra

Case Study 1

A 52-year-old man with a history of prostate cancer treated with brachytherapy and external beam radiation therapy 6 months prior to presentation has a 1-week history of dysuria and urine per rectum. A retrograde urethrogram was performed.

1. What is the next step in the management?
   a. Rectourethral fistula repair through the perineal approach
   b. Fecal diversion
   c. Hyperbaric oxygenation
   d. Fulguration of fistula tract
   e. Observation

Case Study 2

A 60-year-old man with a history of prostate cancer treated with external beam radiation therapy 6 years ago presents with slow urinary stream and dysuria. A retrograde urethrogram is shown.

1. The next step is:
   a. Suprapubic tube drainage
   b. Urethroplasty with buccal mucosa graft
   c. Excision and primary anastomosis
   d. Direct visualization internal urethrotomy
   e. Transurethral incision of the bladder neck

Answers

1. **e.** A recent meta-analysis on the use of HBO for a variety of surgical procedures, including pelvic surgery, suggests that preoperative HBO may reduce wound breakdown, infection, fistula formation, or flap loss after surgery in the irradiated patient. Mechanisms of action discussed in this meta-analysis include stimulation of angiogenesis, reduction of fibrosis, improved tissue oxygenation, and stimulation of stem cells and stem cell derivatives.
2. **c.** The European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines suggest that there may be a benefit of preoperative short-term (7–10 day) parenteral nutrition prior to surgery in a select group of severely malnourished patients unable to sustain enteral supplementation. The American Society for Clinical Nutrition and Metabolism (ASPEN) recommends nutritional supplementation only when enteral intake is impaired. Although consensus is lacking, an assessment of nutritional status through albumin measurement, combined with patient characteristics through a nutritional screening tool, would allow the urologist to properly advise patients on their individual risk of complications related to poor nutrition.
3. **c.** The process of wound healing begins at the moment of injury and is classically divided into four phases: hemostasis, inflammation, proliferation, and maturation. Each stage is predictable in its onset and mediated by the interactions of numerous cell-signaling molecules in a sequential cascade.
4. **b.** This complex process of healing can be interrupted directly or indirectly at several stages by the effects of radiation. Direct effects of radiation on cell proteins and DNA lead to inhibition of cell replication, or cell death through instability or apoptosis. Indirect effects of radiation involve the excitation of intracellular molecules and the generation of free radicals that in turn damage genetic material, signaling mechanisms, and other cell components. Radiation-induced alterations in the expression of several cell-signaling molecules have been documented in both human and animal models. The downstream effects of these alterations include disorganization of extracellular matrices; impairment of neovascularization and cell migration; and disordered collagen deposition leading to compromised blood supply, tensile strength, and the inability to recover from subsequent insults, all contributing to surgical complications in the irradiated field.
5. **d.** A number of healthy tissues are available for interposition when operating through the perineum, but as the peritoneal cavity is not entered directly, the omentum is not accessible without an alternate incisional approach.
6. **d.** While good results have been shown for many iatrogenic RUFs, the York Mason approach has a higher rate of recurrence with radiation-induced strictures (4/7 patients recurred in one study), and larger diameter fistulas, and is therefore not recommended for complex post-radiation RUF, re-do RUF repair, or post-radiation fistulas greater than 2 cm. With the transanal approach, exposure is difficult for proximal fistulas, and this technique does not allow for healthy tissue interposition. Meta-analysis of outcomes after fistula repair demonstrated a higher rate of surgical repair failure for the transanal approach when compared to other approaches. Therefore complex or irradiated RUF using a transanal approach should be avoided.
7. **b.** One study puts the incidence of concurrent urethral strictures at 30% in patients with RUF. Although conservative management with both urinary and fecal diversion has been successful in some patients with small, less fibrotic tissue, it is rarely successful in our experience with post-radiation strictures.
8. **c.** In limited reports of bladder neck reconstruction for contraction following radiation, patients are uniformly incontinent following the procedure. For this reason, simultaneous artificial urinary sphincter placement is usually utilized.
9. **b.** The first step in management of the post–pelvic radiation urethral stricture is the diagnosis of stricture length and location via a retrograde urethrogram (RUG). A suprapubic tube may be necessary in patients with obliterative urethral strictures. In these situations antegrade cystoscopy and concomitant retrograde urethrogram can define a stricture's length and location. Endoscopic management of these strictures, regardless of location and the type of intervention, carries a high rate of recurrence, upward of 50–60%. Additionally, repeat endoscopic procedures have been shown to increase the complexity of strictures and prolong disease duration.

10. **c.** Urinary incontinence is a potential complication following bulbomembranous urethroplasty in the irradiated pelvis. In one series the onset of new postoperative urinary incontinence was 36–50%; however, 20% of these patients (3/15) experienced spontaneous resolution of their incontinence 4 weeks after surgery. If incontinence does not resolve, an artificial urethral sphincter can be offered. As in nonirradiated patients, it does not appear that erectile function is significantly altered following anterior urethroplasty in men with previous pelvic radiation.
11. **a.** The pathophysiology of urethral stricture in the post-radiation patient is related to chronic oxidative stress subsequently leading to vascular damage, ischemia, and poor wound healing of the surrounding tissue. The resulting fibrosis of the corpus spongiosum leads to urethral stricture formation, which can present several years following the completion of therapy, and is typically found in the bulbar urethra extending to the prostate.

CASE STUDY 1

1. **b.** The retrograde urethrogram and cystogram picture clearly demonstrate an enteric fistula to the lower urinary tract. Given this patient's prior history of radiation, fecal diversion is mandatory and the first step in management, prior to repair. Consideration should also be given to suprapubic drainage of the urine away from the fistula. While hyperbaric oxygenation has been shown to aid wound healing and prevent fistula formation in the previously irradiated field, it is not a treatment option for an active fistula. Fulguration of the fistula tract is unlikely to be successful given the patient's prior radiation and the extent of the fistula as evidenced by the amount of extravasated contrast. Observation will not improve the patient's condition.

CASE STUDY 2

1. **b.** The retrograde urethrogram demonstrates a relatively long post-radiation urethral stricture best managed with graft interposition. Excision and primary anastomosis is best reserved for men with strictures <2 cm. Endoscopic management via direct visual internal urethrotomy has been shown to have a high rate of recurrence in men with previous pelvic radiation and may increase the complexity of strictures and prolong disease duration. Transurethral resection of the bladder neck would not address this patient's urethral stricture. Suprapubic drainage is not necessary in this case as the patient is voiding and there is no indication of urinary retention.

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SECTION IV

Complications of Ambulatory Urologic Procedures

20 Prostate Biopsy Complications

MEENAKSHI DAVULURI and STACY LOEB

CHAPTER OUTLINE

Introduction
Prostate Biopsy Complications and Factors Influencing Complications
Bleeding Complications
Infectious Complications
Lower Urinary Tract Symptoms and Acute Urinary Retention
Erectile Dysfunction
Pain
Mortality
Complications of Alternative Biopsy Technique: Transperineal Biopsy
Methods to Decrease Complication Risks
Management of Complications
Conclusion
Chapter 20 Questions and Answers

KEY POINTS

1. Prostate biopsy complications can range from minor complications such as pain, mild hematuria, and hematochezia to severe infectious complications including sepsis, and very rarely death.
2. Bleeding is the most common complication, but usually self limiting. The discontinuation of aspirin pre-biopsy does not appear to significantly impact post-biopsy bleeding.
3. The rise in infectious complications is likely due to an increase fluoroquinolone resistance that has been demonstrated in recent studies. Various antibiotic regimens have been proposed, but it is important for institutions to look at their local antibiogram.
4. Patient risk factors that increase chance of post-biopsy infection include immunosuppression, diabetes mellitus, recent antibiotic use, and foreign travel.
5. There appears to be no significant difference in complications when comparing between standard TRUS biopsy and transperineal template guided biopsy.
6. Patient education regarding potential complications is critical for early recognition and treatment of post-biopsy complications.

Introduction

It has been estimated that 1 million transrectal ultrasound-guided biopsies (TRUS-bx) are performed annually in the United States. These biopsies are done by insertion of an ultrasound probe into the rectum. A biopsy needle is then used to take samples of prostate tissue in a systematic manner. The 2016 National Comprehensive Cancer Network Guidelines recommend sampling 12 cores for initial and repeat prostate biopsy.[1] Although anteriorly directed biopsies are not recommended routinely, additional transition zone biopsies may be considered in the repeat biopsy setting.

Recent improvements in magnetic resonance imaging (MRI) technology are leading to a substantial shift to targeted prostate biopsy. This can be performed several ways including MRI-TRUS fusion, cognitive co-registration, or in-gantry MRI-targeted biopsy.

There are several known significant major and minor complications associated with prostate biopsy (Table 20.1). Minor complications include pain, lower urinary tract symptoms, urinary retention, infection, and self-limited bleeding. There is also a possible link to erectile dysfunction. Major complications are uncommon but include hemorrhage, sepsis and, very rarely, death. Additionally, this procedure can be associated with significant anxiety and discomfort for the patient.

Prostate biopsy complications have been increasingly recognized in recent years and are an important consideration when weighing the benefits and harms of prostate cancer screening. For this reason, the risk of complications is now included in some risk calculators designed to help patients weigh the pros and cons for prostate biopsy decisions.[2]

Prostate biopsies are also performed in other clinical scenarios, such as active surveillance and evaluation for local recurrence after treatment. The complications associated with this procedure will be discussed in detail including prevention strategies and management of complications (Table 20.2).

Prostate Biopsy Complications and Factors Influencing Complications

BLEEDING COMPLICATIONS

Bleeding is the most common complication associated with TRUS-bx and includes hematuria, rectal bleeding, and hematospermia.

Visible hematuria is reported in 10–84% of cases; however <1% is severe enough to require catheterization and hospitalization.[3] More than 90% of men reported that hematuria was not a significant burden.[4] Most hematuria resolves within 3 days; however, for 22% of patients it may persist for a longer period.[5] This is associated with a larger prostate and transition zone volume. Additional factors that increase the risk of hematuria are pre-biopsy enemas and use of anticoagulation.[5,6] Repeat biopsies and needle size are not associated with increased hematuria.[3] There are conflicting data on whether the number of cores sampled impacts hematuria severity or duration.[3]

Rectal bleeding is observed in 1.3–45% of cases.[3] Usually patients consider this minor with <2.5% of cases considered moderate or severe.[4] Factors influencing the risk of rectal bleeding include number of cores sampled and use of anticoagulation. As with hematuria, needle size does not appear to impact risk of rectal bleeding.[3]

The frequency of hematospermia after biopsy varies widely in the literature, with reported rates of 1.1–93%.[3] However, hematospermia is also transient and resolves with repeated ejaculation. The reported median duration is 12–20 days or approximately eight ejaculations, although this also varies.[3,7,8] Patients should be counseled on the specific risk of hematospermia as social factors and cultural barriers could prevent patients from seeking medical attention if this occurs. Factors increasing the risk of hematospermia are larger prostate volume, previous transurethral resection prostate (TURP), and the number of cores sampled.[3]

It is important to note that while the majority of bleeding complications are self-limiting, in rare cases significant hematuria or rectal bleeding can be life threatening. Patients should be appropriately counseled on these risks as part of the informed consent process for prostate biopsy.

The impact of anticoagulation on bleeding is a concern for many urologists. Comparison of patients on aspirin and off aspirin has not been associated with any difference in significant bleeding events. However, patients on aspirin do seem to notice that minor bleeding may have a longer duration than for patients not on anticoagulation.[3,9] Current practice recommendations have concluded that it is therefore safe to continue antiplatelets during prostate biopsy.[10]

There are fewer data on the effects of anticoagulants such as warfarin and clopidogrel.[3] Additionally the impact of newer anticoagulation drugs such as factor X inhibitors rivaroxaban and apixaban have not been well-studied in this context, and the risk of serious complications is unknown.[10]

Table 20.1 Potential Side Effects/Complications of Prostate Biopsy

Pain/Anxiety

Urinary Side Effects
- Lower urinary tract symptoms
- Acute urinary retention
- Hematuria

Sexual Side Effects
- Hematospermia
- Reduction in sexual function

Bowel Side Effects
- Hematochezia

Infectious Complications
- Urinary tract infection
- Sepsis

Death (rare)

INFECTIOUS COMPLICATIONS

Some well-documented risks of prostate biopsies include infectious complications such as urinary tract infection, bacteremia, sepsis, and, in rare cases, death. The risk of hospitalization due to infection ranges from 0% to 6.3%.[3] Data from SEER-Medicare showed that men undergoing prostate biopsy had a 2.26 greater risk of 30-day hospitalization for infection compared to randomly selected controls.[11] Furthermore, there has been a plethora of data showing a significant increase in hospitalization rates over time in the United States and globally.[11–13]

Table 20.2 Influencing Factors, Treatment, and Prevention of Prostate Biopsy Complications

Complication	Influencing Factors	Treatment	Prevention
Hematuria	■ Anticoagulation ■ Number of cores	Observation, may require catheterization and continuous bladder irrigation	■ Discontinuation of anticoagulation (except aspirin)
Infection	■ Fluoroquinolone-resistant *E. coli* ■ Comorbidities, recent travel, recent antibiotic use	Antibiotics	■ Proper sterilization tactics ■ Screening for risk factors ■ Knowledge of local antibiogram ■ Rectal swabs
Urinary retention	■ Prostate size and volume	Urethral catheterization	■ Periprocedural alpha-blockers
Erectile dysfunction	■ Anxiety from prostate cancer diagnosis	Observation, medical management	■ Appropriate counseling

This is thought to be due to increased prevalence of fluoroquinolone-resistant *Escherichia coli* worldwide, with up to 37% of *E. coli* isolates being flouroquinolone resistant in parts of Asia.[14] This has also been reported in the African continent as well as parts of Europe.[15,16] It has been shown that foreign travel is an independent risk factor for post-biopsy infection and sepsis, with approximately a six times increased risk of fluoroquinolone-resistant *E. coli* for patients who recently traveled abroad.[17] Additionally, recent antibiotic use increases the risk of post-biopsy infection, as antibiotics can cause a change in normal bowel flora.[3,17]

It has been shown that a particular *E. coli* strain, ST131, has demonstrated an increased resistance to fluoroquinolones worldwide. A small number of studies have isolated this strain as a significant contributor to the increased rate of sepsis associated with prostate biopsies in recent years. Up to 35% of patients who suffered from post-biopsy sepsis grew this *E. coli* strain.[18]

Other patient-specific factors shown to increase the risk of prostate biopsy infections include comorbid medical conditions such as diabetes and conditions with immunosuppression.[3] These patients at baseline are more prone to infections and sepsis and should undergo further counseling on the increased risks prior to proceeding with prostate biopsy. Diabetic patients should additionally be counseled on the importance of glucose control and compliance with medical therapy.

Factors such as age, prostate specific antigen (PSA), and prostate volume do not appear to be associated with an increased risk of infection. However, there has been a reported five-fold increased risk of developing sepsis if preprocedure WBC was greater than 11.2 /μL.[19] Certainly any patients with a symptomatic urinary tract infection should undergo testing and treatment for that prior to prostate biopsy.[10]

Procedural factors may also increase the risk of infectious complications. There are documented instances of infections related to contaminated ultrasound gel and improper processing of the equipment.[20]

Finally, the impact of repeat biopsies on the risk of infection has received significant attention, since approximately 38% of US men with a negative biopsy undergo another biopsy within 5 years.[21] This is also germane in light of recent increases in the use of active surveillance, with an estimated 40–50% of low-risk men in the United States choosing conservative management as of 2013.[22,23] More recent data from Sweden reported higher rates of active surveillance, with 2014 rates of 91% of very-low-risk, 74% of low-risk, and 19% of intermediate-risk patients diagnosed nationwide.[24] In the major prospective active surveillance programs, the frequency of repeat prostate biopsy ranges from annual to every 5 years.[25] As this strategy increases globally, this can be expected to increase the number of patients continuing to have repeated prostate biopsies over the course of many years after their diagnosis.

Whether men undergoing repeat biopsy have greater risks has been previously studied. Data from SEER-Medicare reported that, although performing repeat biopsies increases the chance of patients experiencing a complication in a cumulative way, the actual repeat biopsy procedure had a similar risk of serious infectious complications compared to the initial biopsy procedure.[26] A recent series from the Prostate Cancer Research International Active Surveillance (PRIAS) study reported infection after 2.5% of biopsies.[27] Biopsy number was not a significant independent predictor of infectious complications. However, it is noteworthy that patients experiencing a complication were less likely to undergo their next protocol-recommended biopsy. The risks of serial prostate biopsy are an important component of patient counseling regarding active surveillance.

LOWER URINARY TRACT SYMPTOMS AND ACUTE URINARY RETENTION

In the immediate postprocedure period, patients may experience symptoms such as dysuria in approximately 6–25% of cases.[3] These symptoms are usually transient and resolve.

The risk of acute urinary retention is 0.2–1.7% following transrectal prostate biopsy, although higher rates have been reported following transperineal biopsy.[3] The use of alpha-blockers such as tamsulosin has been shown to produce a statistically significant decrease in International Prostate Symptom Score (IPSS).[28] Therefore these can be prescribed to patients who may be at higher risk for urinary retention, although premedication is not necessary for every patient.

Factors that have been shown to increase the risk of urinary problems after biopsy include larger prostate size, ratio of transition zone volume to total prostate volume, and higher IPSS scores.[5,6] There does not appear to be a correlation between the number of biopsy cores taken or the number of repeat serial biopsies performed and LUTS.[3,27]

ERECTILE DYSFUNCTION

There are mixed data regarding the impact of prostate biopsy on erectile dysfunction. The most common measure of erectile dysfunction post-biopsy is the International Index of Erectile Function (IIEF).

The exact etiology of erectile dysfunction after biopsy is unknown, but it may be due to inflammation in the immediate post-procedure period as well as minor damage to the neurovascular bundle from needles.[3] There has been some speculation that a component of erectile dysfunction may be related to the psychological impact of concerns about cancer or receiving a prostate cancer diagnosis.[29] It has been shown that 19% of men who underwent a negative prostate biopsy were more worried about prostate cancer and had a moderate to severe impact on sexual function compared to 10% of age-matched control patients.[30] Another study showed that men who underwent TRUS-bx and received a positive prostate cancer diagnosis had a lower post-biopsy IIEF score compared to those men who had a negative prostate biopsy.[31]

However, studies that have established a baseline of erectile function prior to biopsy have shown that IIEF scores return to normal within 6 months.[32] While there may be a transient short-term increase in erectile dysfunction after a single biopsy, most patients return to baseline after an initial prostate biopsy.[33] Factors that have been associated with the risk of erectile dysfunction include periprostatic local anesthetic nerve block and the psychological impact of the anxiety associated with prostate cancer diagnosis.[3] Factors that have not been show to impact erectile dysfunction after biopsy include PSA, prostate volume, and number of cores.[3]

Another factor that has been associated with the risk of erectile dysfunction is biopsy number. In particular there is concern as to whether repeated biopsies performed during active surveillance could increase the risk of erectile dysfunction. In the Johns Hopkins active surveillance program, there was a reduction in sexual function scores on later transrectal prostate biopsies.[34] Similarly, a recent study from the United Kingdom found that erectile function scores returned to baseline 6 months after the first transperineal sector biopsy, but had not fully returned to baseline at 6 months after the second transperineal sector biopsy.[33] Other active surveillance studies did not find a significant relationship between repeated prostate biopsy with erectile dysfunction.[35] It is important to recognize that during the course of active surveillance patients are also aging and may experience changes in other risk factors as well, making it difficult to isolate the effects of repeated prostate biopsies.[36] Nevertheless, this possible issue should be discussed with men considering active surveillance, particularly since preservation of sexual function is one of the reasons patients may opt to defer radical treatment.

PAIN

Use of analgesia has been shown to reduce pain during prostate biopsy. Factors worsening pain include anorectal compliance, number of biopsy cores, younger age, and anxiety.[3,37] Pain can be a significant barrier for men requiring a repeat biopsy, with up to 18% of men reporting they would refuse repeat biopsy.[38] There are multiple options for prostate biopsy anesthesia, ranging from local options such as lidocaine gel and periprostatic nerve block, to sedation and general anesthesia. Combined approaches to anesthesia are also possible, such as combining gel and periprostatic nerve block, or sedation plus periprostatic nerve block.[39]

There has also been investigation into other simple techniques to reduce pain and anxiety with prostate biopsy. A recent study showed that waiting an additional 5 minutes after administering periprostatic nerve block did not significantly reduce pain.[37] However, simple maneuvers like patient positioning also may affect the level of pain, and listening to music is another optional technique to reduce anxiety.[40]

MORTALITY

The risk of death after prostate biopsy is extremely small, likely due to careful patient selection for prostate biopsy. Some studies have even shown a lower risk of overall mortality within a 30-day period among men undergoing biopsy compared to controls from the population.[11] However, the risk of death after prostate biopsy is significantly higher in patients who develop sepsis,[11] highlighting the importance of prevention and effective management for infection in this population.

During the preprocedure, informed consent and the need for prompt follow-up with a health-care provider if the patient experiences any symptoms should be discussed thoroughly. Understanding where and how these patients with complications present can also be crucial in timely management of TRUS biopsy complications.

Complications of Alternative Biopsy Technique: Transperineal Biopsy

Transperineal biopsy (TP-bx) is an alternate prostate biopsy strategy in which the rectum is avoided completely and samples are taken by accessing the prostate through the perineum. Overall, there does not appear to be a significant difference in total complication rates between TP-bx and ultrasound-guided TRUS-bx, although the profiles may differ slightly. Similar to TRUS-bx, TP-bx may be associated with pain, hematuria, urinary retention, infection, and possibly erectile dysfunction. Additionally there have been reports of scrotal swelling and perineal ecchymosis, which self-resolve.[3]

A possible advantage of TP-bx is the decreased infectious complications rate, as the rectum is avoided with this approach.[41] This can be a significant factor for patients at higher risk of infection. The 2016 AUA White Paper lists this as an optional strategy for prevention of infection.[10] However, TP-bx often involves a greater number of cores, which increases the risk of urinary retention. As discussed earlier, periprocedural alpha-blockers may be used to reduce this risk.

Overall, the European Association of Urology (EAU) guidelines state that both TUS-bx and TP-bx are acceptable strategies for prostate biopsy, and a recent review by the Australian guidelines panel concluded that there is a lack of evidence to determine whether the transperineal or transrectal approach is more effective in preventing adverse events.[42,43] The risks and benefits of both methods can be discussed with the patient.

Methods to Decrease Complication Risks

Since most bleeding after prostate biopsy is minor and short in duration,[4] there has been debate over the necessity of discontinuing anticoagulation. Important factors to consider include the indication for use and type of anticoagulant.[3] Because the frequency of serious bleeding complications is extremely low, the 2016 American Urological Association (AUA) White Paper and EAU guidelines suggest that TRUS-bx is safe without stopping aspirin beforehand, though there are fewer data available regarding other anticoagulants such as warfarin and clopidrogel.[10,42]

Fig. 20.1 summarizes important steps in the prevention of infectious complications. The first step is to ensure that proper cleaning and sterilization practices are being used for all equipment. Reusable prostate needle guides require cleaning then heat sterilization.[10] The American Institute of Ultrasound in Medicine has published guidance regarding the specific processing of reusable ultrasound transducer probes.[44]

All patients with an upcoming prostate biopsy should be screened for risk factors, including comorbidities, recent medications, hospitalizations, and foreign travel.[10] Antibiotic prophylaxis has been shown to reduce the risk of bacteriuria, bacteremia, and clinical infections, and routine

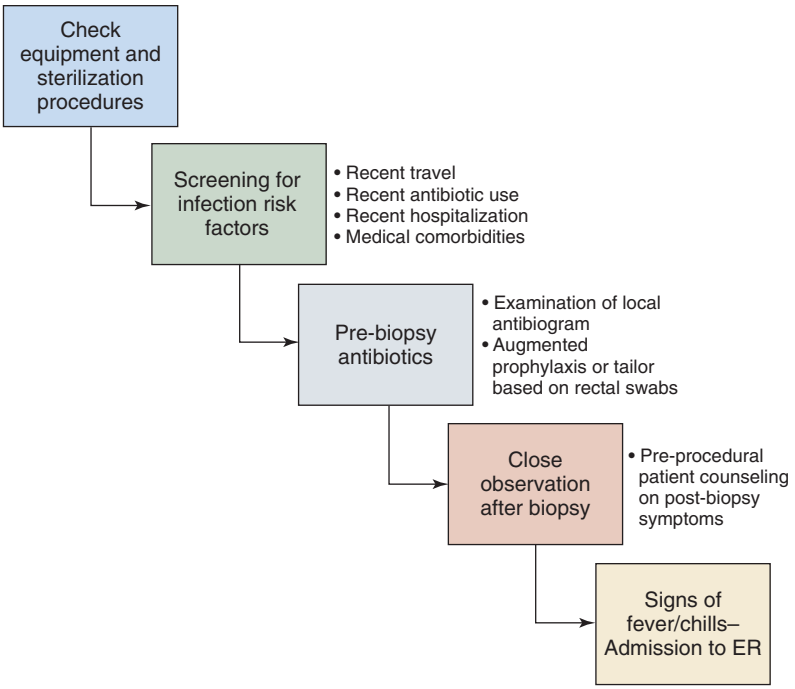


Figure 20.1 Flowchart of steps for prevention and evaluation of biopsy-related infection.

antimicrobial prophylaxis is recommended for all prostate biopsies by multiple international guidelines.[45] The AUA Best Practice Policy Statement on Urologic Surgery Antimicrobial Prophylaxis recommends a duration of less than 24 hours for prostate biopsy prophylaxis.[45] Longer duration antibiotic use has not been shown to reduce infections and could promote resistance.

The choice of antimicrobial agents recommended for prostate biopsy includes fluoroquinolones, first-/second-/third-generation cephalosporins, and trimethoprim-sulfamethoxazole.[45] An alternative is IM/IV aminoglycoside or aztreonam. While fluoroquinolone antibiotics remain the most commonly prescribed for prostate biopsies worldwide,[46] increasing fluoroquinolone resistance has led to a search for alternative options.[47]

With respect to empiric prophylaxis, the 2016 AUA White Paper recommends examining the local antibiogram to choose the best option within those offered in the AUA guidelines. It also presents the options of antibiotic augmentation (e.g., fluoroquinolone plus cephalosporin, aminoglycoside, amikacin, or fosfomycin) or targeted prophylaxis.[10]

Performing a rectal swab culture prior to biopsy and giving targeted prophylaxis are alternative options for reducing the risk of infection with fewer total antibiotics.[48] However, rates of resistance on rectal swab cultures are substantially higher than the rate of clinical infections. The cost-effectiveness of this practice in an average-risk population requires further study since the overall event rate of serious infectious complications is low. However, this option should be offered to high-risk patients, defined as those with previous antibiotic exposure or known resistance in the past, those who undertake frequent international travel, health-care workers, or immunosuppressed patients. Finally, consultation with infectious disease service is recommended for immunocompromised patients.[10]

The use of bowel preparation as a way to decrease infections has been studied as well. Results are mixed with some studies showing that it could half the rate of infection[49] and others showing no impact on post-biopsy complication rates.[6] The differences in these findings can be attributed to various uses of antibiotics, various end points for infection, and geographical differences in patient population. Various bowel preparations have been compared, including simple phosphate enemas, laxatives, and polyethylene glycol. No specific bowel preparation has been shown to be superior.[6,50,51] Overall it does not appear that bowel prep decreases the rate of infectious complications significantly, and prophylactic antibiotics appear to be sufficient.[3,6]

Men with lower urinary tract symptoms should be screened for infection prior to biopsy,[10] and periprocedural alpha-blockers may be prescribed for high-risk patients to prevent urinary retention. Men should be told to void after the biopsy while still in the clinical setting, and the post-void residual urine volume can be measured if the patient has difficulty. If the patient is unable to void, a Foley catheter may need to be placed to relieve the acute symptoms of urinary retention. The patient may follow up in clinic for a trial of void after 1–2 days.

All patients undergoing biopsy should be counseled preemptively to seek prompt medical attention if issues develop at home. In particular, patients should present to the emergency department for fevers and chills. Although some complications can be managed as an outpatient,[52] this general practice allows appropriate evaluation and triage.

Management of Complications

Intervention or hospitalization is rarely required for bleeding after prostate biopsy. Significant gross hematuria can be

managed with clot irrigation and external traction for a compressive effect, as well as cystoscopy and coagulation for refractory cases.[10]

Patients often experience rectal bleeding at first postural change to a standing position or upon first attempt at bowel movement. Much of this may reflect evacuation of bleeding that occurred during the biopsy rather than active bleeding. Evacuation of clots may lead to a vasovagal reaction and presyncope/syncope resulting in potential traumatic injury. As such, men who do not have active bleeding during the biopsy should be observed for a period of time in the recumbent, then seated position to determine if active bleeding is present. Gentle manual distraction of the anal sphincter upon removal of the probe will often demonstrate the presence of blood in the rectum. In such cases, a long gauze packing can be generously lubricated and advanced into the rectum for purposes of rectal packing and tamponade. The packing should be left in place for 3–5 minutes and removed. Serial packings can be employed as necessary until bleeding is stopped. In our experience, this technique with manual pressure is quite effective and has the added advantage of soaking up any blood already present in the rectosigmoid lumen.

In the rare event that massive rectal bleeding occurs the treatment options include rectal balloon tamponade, endoscopic adrenaline injection or sclerotherapy, or direct vessel clipping.[3] If rectal bleeding continues, the patient can be admitted and undergo consultation with general surgery, interventional radiology, and/or gastroenterology.[10]

There has been no proven technique that can be used intraprocedurally or postprocedurally to decrease bleeding rates significantly. Holding pressure with biopsy probe in the needle tracts postprocedurally has been attempted but no significant changes in bleeding have been reported.[53] Therefore knowledge regarding management of these complications postprocedurally is important.

Vasovagal reaction with potential syncope due to rectal manipulation/distention and bladder pressure can occur during the biopsy, immediately after, or even at delayed intervals up to 1–2 hours after the procedure. Patients should be encouraged to come to the biopsy having eaten some food earlier in the day, and should maintain good hydration status. Patients experiencing nausea, diaphoresis, or dizziness during the procedure (indicative of vasovagal response) should be managed by cold compress placement and blood pressure monitoring. If symptoms persist, the rectal ultrasound probe should be removed until the patient's symptoms improve. Following the biopsy, patients should be observed for a minimum of 30 minutes to ensure they are feeling well. Persistent symptoms of nausea, lightheadedness, diaphoresis, or sensation of rectal or bladder fullness should prompt longer observation until resolution.

Patients who present with a fever following biopsy should be evaluated promptly since timely intervention is essential to prevent worsening. Patients should be evaluated for the presence of sepsis, to avoid progression to septic shock. Fever, accompanied by chills or rigors, should result in hospitalization for intravenous antibiotics rather than outpatient oral medications.

Management of patients with severe infection should include aggressive fluid resuscitation and initial broad-spectrum antibiotic coverage (third-generation cephalosporin and aminoglycoside) after urine and blood cultures are taken. The AUA White Paper states that oral Bactrim should not be used if bacteremia is suspected.[10] Antibiotic management can be tailored later as necessary based on culture results. If hypotensive or tachycardic, patients should be admitted to a monitored setting. Urinary retention should be ruled out and, if present, gentle catheterization or suprapubic cystostomy should be considered. In the very sick patient, urethral catheter and rectal exam should be avoided due to the risk of secondary bacteremia from prostate manipulation.

Most urinary symptoms after prostate biopsy resolve spontaneously. Retention post-biopsy may require catheterization and alpha-blockers. Patients should be asked to void before departure following biopsy, and in cases of concern, post-void residual should be monitored. If patients call with persistent irritative symptoms, frequency, or urgency after biopsy, in addition to ruling out infection, retention should NOT be discounted.

Conclusion

The risk of prostate biopsy complications is an important factor in discussions with patients considering diagnostic biopsy, as well as biopsies performed for restaging in men with a diagnosis of prostate cancer. Most prostate biopsy complications are minor, with the most common being bleeding. Hematuria, hematochezia, and/or hematospermia may occur but typically resolve spontaneously over time without intervention. Infection after transrectal prostate biopsy has increased in frequency despite the standard use of antimicrobial prophylaxis. This is thought to be due to an increasing frequency of fluoroquinolone resistance in the population. These complications may be potentially life-threatening, requiring prompt evaluation and management. To reduce the risk of infection, equipment must be sterilized in accordance with guidelines, and patients should be screened for risk factors including co-morbidities and exposures that might increase the risk of harboring resistant bacteria. Augmented or targeted antimicrobial prophylaxis, or alternate biopsy techniques such as a transperineal approach, can be considered to reduce infection risk. Pain with prostate biopsy can be effectively reduced with anesthetics and, possibly, anxiety reduction techniques. Lower urinary tract symptoms are typically transient, but periprocedural alpha-blockers may be prescribed to reduce the risk of acute urinary retention for patients with significant prostate enlargement and those undergoing transperineal prostate biopsy. Changes in erectile function after a prostate biopsy have also been reported; while mostly transient, the potential impact of multiple repeat biopsies on erectile function requires further study. All patients undergoing prostate biopsy must be informed about the potential complications of the procedure.

References

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Chapter 20 Questions

1. Which of the following complications has been occurring with increasing frequency in recent years?
   a. Urinary retention
   b. Hematuria
   c. Erectile dysfunction
   d. Infection
   e. Hematospermia

2. Which of the following factors is associated with an increasing risk of biopsy infection?
   a. Increased number of cores
   b. Increased number of overall TRUS biopsies done
   c. Increasing prevalence of fluoroquinolone resistance
   d. The use of rectal swabs before TRUS biopsies
   e. Increased prevalence of repeat TRUS biopsies being done

3. Which of the following techniques has been used to try to decrease infection after prostate biopsy?
   a. Use of rectal swab to tailor prophylactic antibiotics
   b. Rectal cleansing with povidone-iodine before TRUS biopsy
   c. Expanding antimicrobial regimen
   d. Rectal prep including enemas preprocedurally
   e. All of the above

4. Which is the most common complication after biopsy?
   a. Minor bleeding
   b. Urinary retention requiring catheterization
   c. Hemorrhage
   d. Sepsis
   e. Erectile dysfunction

5. Which of the following has been shown to decrease the risk of acute urinary retention/LUTS symptoms after transperineal biopsy?
   a. Expanded antimicrobial prophylaxis
   b. Use of alpha-blockers
   c. Use of smaller gauge biopsy needle
   d. a and b
   e. None of the above

6. Which of the following statements about biopsy preparation is FALSE?
   a. Patients should have informed consent before biopsy
   b. All patients should receive antimicrobial prophylaxis before transrectal biopsy
   c. Use of anesthetic agents reduces pain with biopsy
   d. Fluoroquinolones are the most common antibiotics prescribed for prostate biopsy
   e. Aspirin must always be discontinued before prostate biopsy

7. Which antibiotics are NOT among the options for empiric prostate biopsy prophylaxis according to the AUA Best Practice Policy?
   a. Fluoroquinolones
   b. Aminoglycosides
   c. Nitrofurantoin
   d. Cephalosporins
   e. Trimethoprim-sulfamethoxazole

8. Which of the following complications is usually minor and self-limited?
   a. Hematospermia
   b. Hematuria
   c. Hematochezia
   d. All of the above
   e. None of the above

9. Which of the following patient factors increases the risk of biopsy infections?
   a. Diabetes
   b. Immunosuppression
   c. Recent foreign travel
   d. Antibiotic use
   e. All of the above

10. Compared to transrectal biopsy, transperineal prostate biopsy may reduce the risk of the following complications:
    a. Infection
    b. Perineal ecchymosis
    c. Urinary retention
    d. Scrotal swelling
    e. All of the above

Case Studies

CASE 1

A 58-year-old male patient presents with an elevated PSA and suspicious lesion on MRI.

1. Which risk factors should be evaluated in this patient as part of the pre-biopsy evaluation?
   a. Comorbid medical conditions
   b. Recent illness and antibiotics
   c. History of urinary tract infection or retention
   d. All of the above
   e. None of the above

Upon further questioning, the patient mentions that he had an infection after a previous prostate biopsy 3 years ago.

2. Which statement about repeat prostate biopsy is TRUE?
   a. A greater number of biopsies increases the cumulative risk of experiencing a complication
   b. The repeat biopsy procedure has a greater risk of infection than the initial biopsy procedure
   c. Repeat biopsy is associated with a greater risk of death
   d. Alpha-blockers are always used for repeat biopsy
   e. There is an increased risk of urinary retention associated with repeat prostate biopsies

The patient is concerned about having infection with this biopsy.

3. What is a possible strategy to reduce the risk of prostate biopsy infection?
   a. Use transperineal approach
   b. Augmented prophylaxis
   c. Targeted prophylaxis using rectal swab culture
   d. Screening for risk factors such as recent travel, hospitalizations, antibiotic use, and co-morbidities
   e. All of the above

CASE 2

A 67-year-old male patient with a past medical history of hypertension and type II diabetes mellitus calls the office complaining of fever, chills, and nausea. He underwent a prostate biopsy the previous day with fluoroquinolone prophylaxis.

1. What is the appropriate management?
   a. Recommend patient go to the emergency room for further evaluation
   b. Prescribe antibiotics over the phone and have patient come to office the next day for urinalysis and culture
   c. Observation as this can be a common occurrence post-biopsy
   d. Recommend that the patient get in touch with his primary care physician as his symptoms are likely not related to the prostate biopsy
   e. None of the above

The patient presents to the emergency department.

2. What should be done as part of initial management?
   a. Blood culture
   b. Urine culture
   c. Start broad-spectrum antibiotics
   d. All of the above
   e. None of the above

The patient is hospitalized and cultures grow fluoroquinolone-resistant *E. coli*. His fever gradually resolves and he is discharged on culture-specific oral antibiotics. Two days later he calls the office concerned after seeing blood in his ejaculate.

3. What is the correct advice regarding hematospermia?
   a. Full hematuria workup is required with cystoscopy and CT urogram
   b. Hematospermia suggests the presence of sepsis
   c. Most cases are transient and will resolve with subsequent ejaculations
   d. Immediate medical attention is needed for hematospermia after biopsy
   e. Hematospermia is an uncommon event after prostate biopsy

Answers

1. **d.** The risk of infection after prostate biopsy has increased recently, whereas the frequency of other complications has remained relatively stable.
2. **c.** Fluoroquinolones are historically the most commonly used antibiotics for prostate biopsy, and resistance has increased recently, resulting in an increase in infectious complications.
3. **e.** Rectal swab cultures, rectal cleansing, expanded antibiotic prophylaxis, and rectal prep are all techniques that have been employed in an effort to reduce the frequency of infection after biopsy.
4. **a.** Minor bleeding in the urine, stool, and/or ejaculate is the most common complication after biopsy and is usually self-limiting.
5. **b.** Prescribing alpha-blockers periprocedurally has been shown to reduce the risk of acute urinary retention after transperineal biopsy. None of the other strategies has been shown to help with this.
6. **e.** Prostate biopsy may be performed on aspirin, which has not been associated with an increased risk of serious bleeding complications.
7. **c.** Fluoroquinolones, aminoglycosides, cephalosporins, and trimethoprim-sulfamethoxazole are all options for prostate biopsy prophylaxis, whereas nitrofurantoin is not.
8. **d.** Bleeding complications are frequent after prostate biopsy but are usually minor and self-limiting.
9. **e.** Diabetes, immunosuppression, recent foreign travel, and recent antibiotic use can all increase the risk of infection after biopsy.
10. **a.** Transperineal biopsy is associated with minimal risk of infectious complications by avoiding the rectum. However, it may have other complications such as perineal ecchymosis, urinary retention, or scrotal swelling.

CASE 1

1. **d.** The patient's full medical history should be assessed before biopsy including comorbidities, recent illnesses and antibiotic use that could increase the risk of resistance, and a history of urinary tract infection or retention.
2. **a.** Although the repeat biopsy itself has a similar risk of infection and retention, the more biopsies a patient undergoes the greater the cumulative risk of experiencing a complication. Alpha blockers are not required to be used in every repeat biopsy but can be used to help decrease the risk of urinary retention of patient has experienced that complication previously.
3. **e.** Changing the approach to transperineal, giving augmented antibiotic prophylaxis, rectal swab cultures, and engaging the patient in a thorough history to evaluate particular risk factors are all strategies that can assist in decreasing risk of infection with biopsy.

CASE 2

1. **a.** Patients with signs or symptoms of infection after biopsy should proceed directly to the emergency room since prompt evaluation is essential.
2. **d.** A patient presenting with infection after prostate biopsy should have prompt evaluation with blood and urine cultures and initiation of broad-spectrum antibiotics.

3. **c.** Hematospermia is a common complication after prostate biopsy but is usually minor and resolves spontaneously with repeated ejaculation. Therefore, immediate medical attention is not needed. Low dose aspirin has not been shown to significantly worsen bleeding complications associated with prostate biopsies including hematospermia. However, the impact of other anticoagulation such as warfarin, clopidogrel, and factor X inhibitors is unclear. Hematospermia is not a definitive sign of sepsis.

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21 Complications of Upper Tract Drainage

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CHAPTER OUTLINE

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Surgical Decompression of the Urinary Tract
Indications for Retrograde Ureteral Stents
Indications for Nephrostomy Tubes
Indications for Antegrade Ureteral Stents
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Stent Symptoms
Urinary Tract Infection/Sepsis
Periureteral Fluid Collection (Sterile or Infected)
Wire-related Complications
Stent Migration
Adjacent Organ Injury/Stent Erosion
Stent Encrustation
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Inadequate Relief of Obstruction/ Hydronephrosis
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Complications of Nephrostomy Tubes
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Injury to Intraabdominal Organs
Tumor Seeding
Complications of Antegrade Stents
Conclusion
Chapter 21 Questions and Answers

KEY POINTS

1. Upper tract drainage can be achieved by retrograde ureteral stent placement, percutaneous nephrostomy tube placement or antegrade stent placement.
2. Retrograde stent placement can be complicated by stent symptoms, urinary tract infection or sepsis, wire-related complications, stent migration, encrustation, fragmentation or failure, periureteral fluid collection, adjacent organ injury or fistula formation.
3. Percutaneous nephrostomy tubes can be complicated by tube dislodgement/leakage, urinary tract infection or sepsis, issues related to patient prone positioning, adjacent organ injury, hemorrhage, urine leak, and tumor seeding.
4. Antegrade ureteral stents are usually a two-step process, and their complications are a combination of the two above mentioned procedures.

Introduction

Upper urinary tract (UUT) obstruction is a common urologic condition that can be caused by extrinsic or intrinsic processes. Causes of both types of obstruction are diverse. Extrinsic obstruction may be caused by regional malignancy or retroperitoneal fibrosis, while intrinsic obstruction may be caused by kidney stones, stricture disease, intrinsic neoplasm, or other causes. Drainage of UUT obstruction may be elective, urgent, or emergent depending on the clinical scenario. In general, urgent/emergent procedures are required for obstruction in the setting of infection, bilateral obstruction or blockage of a solitary renal unit, or refractory symptoms such as intractable pain or vomiting.

Drainage procedures can be either internal or external. For the former, "double J" ureteral stents (DJS) were first described by Zimskind in 1967[1] and have since become widely used in urology. For the latter, percutaneous nephrostomy (PCN) drainage was first described by Goodwin in 1955[2] and was first used to drain an infected obstructed system in 1976.[3] There are advantages and disadvantages to each of these procedures, and appropriateness varies by clinical scenario.

In this chapter, we review indications for different types of UUT drainage procedures, and the possible complications of these procedures, with the goal of prevention and rapid effective management.

Surgical Decompression of the Urinary Tract

INDICATIONS FOR RETROGRADE URETERAL STENTS

Retrograde ureteral stents are placed for diverse types of ureteral obstruction, or prophylactically to prevent obstruction after manipulation of the genitourinary (GU) tract. Stents are used to temporize blockage with refractory symptoms, signs of infection, or renal functional compromise, until definitive treatment can be provided. Patients with obstruction and infection should always be decompressed to relieve obstruction prior to UUT manipulation to avoid precipitating urosepsis.

Ureteral stents are commonly used for intrinsic causes of blockage, such as stone disease, ureteral strictures, ureteral tumors, or papillary necrosis. However, stents may also be used for extrinsic processes, for example, retroperitoneal fibrosis (RPF) or regional malignancy. Progressive local processes (for example, malignancy) may render internal drainage less effective over time; however, ureteral stents may still be a useful short-term strategy. Many patients will benefit from chronic internal urinary drainage, especially with relatively stable chronic obstruction due to malignancy or scar tissue, with contraindications to more definitive management (e.g., UUT reconstruction).

DJS, also known as double pigtail stents, are often placed at the conclusion of a ureteroscopic procedure for stones, biopsy, or other manipulations to prevent obstruction from ureteral edema or bleeding. DJS may be used to passively dilate the ureter following ureteroscopy or shock wave lithotripsy, to facilitate passage of stone fragments after stent removal. In the setting of concern for iatrogenic ureteral injury during ureteroscopy, a stent may be left for a longer period of time (e.g., 4–6 weeks) to enable further healing around a buttressed ureter. DJS are placed after UUT reconstruction such as pyeloplasty, reimplant, or ureteroureterostomy to reduce the likelihood of obstruction from ureteral edema and to promote antegrade flow to prevent leakage. Duration of stent placement after these procedures varies depending on provider and local practice patterns. Occasionally stents are placed for flank pain in the setting of equivocal obstruction to determine if pain improves with internal drainage.

"Single J" stents are used during urinary diversion surgery to ensure drainage from the UUT following ureteral implantation, for instance, into an ileal conduit. These are temporary, until they fall out or are removed after a certain interval after surgery.

Finally, ureteral stents may be placed perioperatively for patients undergoing colorectal, gynecologic, or retroperitoneal surgery to enable identification of the ureters intraoperatively with the goal of avoiding iatrogenic injury. These temporary stents are generally 5Fr "open ended" or Pollack catheters that are secured to the Foley catheter and removed at the conclusion of the case or when the Foley is removed.

In patients with bleeding diathesis or active anticoagulation requiring urgent decompression, internal drainage is preferred to external drainage to mitigate the risk of bleeding from percutaneous tube placement.

INDICATIONS FOR NEPHROSTOMY TUBES

Percutaneous nephrostomy (PCN) tubes are placed for more selective indications than are DJS, as retrograde drainage is often preferred due to the lack of an external tube and drainage bag.[4,5] Obstruction is the primary indication for PCN, comprising 85–90% of indications.[6] Indications for PCN include failed internal stenting (inability to place retrograde stent or obstruction despite stenting), obstructive urosepsis (to reduce manipulation of the GU system and possible worsening of clinical infection),[7] patient's preference (e.g., severe stent-related morbidity such as flank pain or irritative symptoms), or for bulky or progressive local malignant processes in which DJS are considered likely to fail.

PCNs may be placed in anticipation of percutaneous nephrolithotomy (PCNL) with strategic placement in a certain calyx to enable direct and/or safe access to the stones of interest, or to enable a percutaneous intervention for an UUT tumor (e.g., antegrade resection or ureteroscopy). Uncommonly, PCNs are used for administration of UUT chemotherapy (e.g., mitomycin or Bacillus Calmette-Guerin [BCG]) for treatment of recurrent or high-grade, noninvasive urothelial cancer.

PCNs may be placed for diagnostic purposes as well. A PCN affords the option of an antegrade contrast study of the UUT that can delineate renal and/or ureteral anatomy for surgical planning (e.g., for stricture disease) or to assess healing of a reconstructed system. PCN can be used for a Whitaker test to assess for UUT obstruction with an equivocal nuclear renal scan. Finally, PCNs may be placed for flank pain and equivocal obstruction to determine if there is relief of symptoms with external drainage.

INDICATIONS FOR ANTEGRADE URETERAL STENTS

Ureteral stents may be placed in antegrade fashion when retrograde stenting is not feasible (e.g., from an impacted stone or with anatomic distortion within an ileal conduit). Patients require percutaneous access for this procedure. Antegrade stenting may enable stent placement in the setting of malignant extrinsic obstruction when retrograde stenting may not be feasible. Chitale et al. reported only a 21% success rate of retrograde stenting, compared to 96% for a two-staged antegrade approach for obstruction due to malignant pelvic disease,[8] with other studies reporting a success rate for antegrade stent placement of up to 88%.[9,10]

It is important to underscore that comparative data for DJS versus PCN for different obstructive indications are generally retrospective and prone to selection bias. Given the absent level 1 evidence, the use of internal verus external drainage for UUT obstruction is often individualized to the patient, with the exception of clear indications for one type of procedure (e.g., PCN for active urosepsis with obstruction).

Complications of Stents

STENT SYMPTOMS

The most common issue related to indwelling DJS is stent morbidity. These symptoms may include flank pain,

abdominal pain, irritative voiding symptoms, bladder spasms, and gross hematuria. Stent symptoms can range from mild to debilitating. In one study of 120 patients with indwelling ureteral stents, 80% of patients experienced bothersome symptoms and 40% reduced work capacity. The most commonly experienced symptoms were pain (80%), and frequency, urgency, or dysuria (60%). Additionally, 40% of patients also reported sexual dysfunction. The authors reported that stent-related symptoms led 40% of patients to seek the assistance of family members in their routine daily activities and 20% to seek medical assistance.[11]

Stent position can exacerbate related symptoms. In particular, incomplete distal curls, distal curls crossing the midline of the bladder, or proximal curls located in a calyx are associated with a higher degree of stent symptomatology.[12,13]

Management of stent morbidity includes ruling out a more significant process, such as urinary tract infection or stent malposition with obstruction. Urine culture, with or without empiric antibiotic treatment, and imaging, such as abdominal x-ray (KUB), can be considered to evaluate these issues. Diverse oral medications can be used to treat stent pain or irritative symptoms such as analgesics, anticholinergics, phenazopyridine, and alpha-1 adrenoreceptor blockers.[14,15] Tamsulosin has been shown to reduce stent-related symptoms in prospective comparative studies.[16,17] A recent randomized study showed that tamsulosin plus tolterodine had no increased reduction of stent morbidity versus tamsulosin alone.[18] Intravesical agent instillations (ketorolac and oxybutynin) have been studied and shown to decrease pain compared to placebo; however this treatment remains uncommon.[19] Other more invasive treatments for stent pain have been studied, including ropivacaine injection around the ureteral orifice, which was shown to potentially decrease pain and voiding symptoms in one study.[20] In another study, botulinum toxin A was injected around the ureteral orifice and was shown to improve postoperative pain and decreased narcotic requirements.[21]

If ureteral stent symptoms are not able to be controlled, hospitalization with intravenous pain control, early removal, or placement of percutaneous nephrostomy tubes can be considered. Finally, given high rates of stent morbidity, thought should be given to the indication for stenting in the first place, and duration of stenting, to reduce patient suffering. While there are data suggesting that stenting after uncomplicated ureteroscopy is not necessary,[22,23] and American Urological Association (AUA) guidelines consider stenting optional after these procedures, provided certain criteria are met (e.g., absence of ureteral injury, normal anatomy, normal renal function),[24] it is common for stents to be placed routinely in patients to avoid the risk of postoperative obstruction. A reasonable approach to stenting is to use a tether to enable easier removal (obviating the need for office cystoscopy) within several days of a procedure; however, this may generate fear of inadvertent dislodgment.[25] Ultimately additional research is needed to improve stent design and pharmacologically reduce morbidity to improve the patient experience related to these procedures.

URINARY TRACT INFECTION/SEPSIS

If ureteral stents are placed in the setting of known urinary infection or sepsis, appropriate antibiotic coverage with culture-specific or broad-spectrum antibiotics is the standard of care. If stent placement is performed without clinical suspicion for infection, a culture should be sent preoperatively if possible; otherwise the American Urological Association Best Practice Statement for antibiotic prophylaxis recommends fluoroquinolone or trimethoprim-sulfamethoxazole (TMP-SMX) as first-line and first-/second-generation cephalosporins, aminoglycoside with or without ampicillin or amoxicillin/clavulanate as second-line prophylactic agents, with consideration of local resistance patterns.[26] Obstruction and infection can readily lead to urosepsis, and while decompression is essential to mitigate risks, instrumentation itself can precipitate bacteremia and hemodynamic instability. Indeed, Flukes et al. reported that 12% of patients with obstructed infected kidney required ICU admission before intervention, and another 6% deteriorated after retrograde intervention, necessitating hemodynamic support in the ICU.[27]

Risk factors for UTI associated with ureteral stents that are in place more chronically include longer duration of stent retention, presence of certain comorbid systemic diseases (diabetes mellitus, chronic renal failure, and diabetic nephropathy), and female gender.[28] Stents removed within 30 days of insertion have a lower risk of UTI compared with those removed after 90 days (6.8% vs 28.6%, respectively). Interestingly, the stent colonization rate was much higher in longer duration stents (64.9% vs 20.5%, respectively).[28]

PERIURETERAL FLUID COLLECTION (STERILE OR INFECTED)

During ureteral stent placement, extravasation of fluid can occur by two mechanisms – either by direct instrument damage (perforation) or indirectly by increased fluid pressure (rupture) (Fig. 21.1). Patients may experience flank pain, fever, and/or ileus, or they can be asymptomatic.[29]

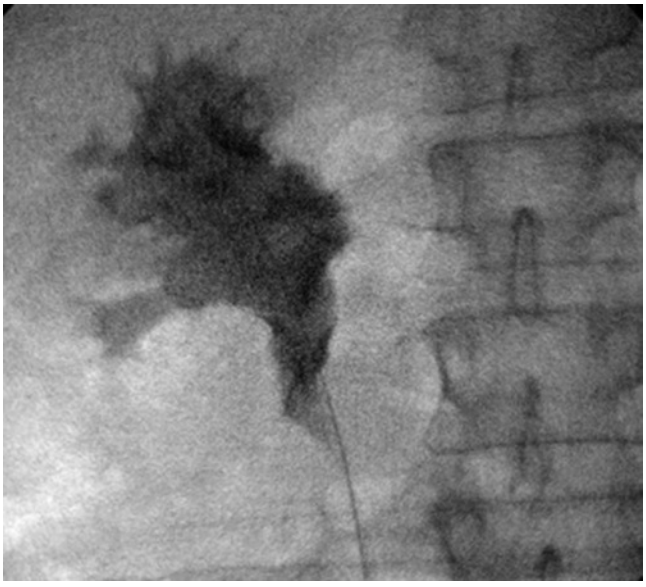


Figure 21.1 Contrast extravasation during retrograde ureteral stent placement.

These events are generally apparent via retrograde pyelography at the time of intervention; however, if there is postoperative concern, cross-sectional imaging will show a fluid collection, which can contain urine, blood, contrast, or irrigation fluid. In rare cases, stone fragments can migrate into this collection, which may be insignificant or may create an abscess in the setting of infection.

Treatment for periureteral collections typically involves a longer duration of ureteral stenting to encourage antegrade urine flow and buttress the injured ureter. If a patient has worsening symptoms or is clinically infected, a percutaneous drain may be required. Intravenous antibiotics and inpatient observation may be required depending on the clinical scenario. If there is persistent urinary drainage into a periureteral collection, proximal diversion of the urine via nephrostomy tube drainage is indicated. Unless there is a foreign body or abnormal tissue such as in prior radiation therapy, a ureteral perforation should heal within 2–4 weeks of ureteral stenting.

WIRE-RELATED COMPLICATIONS

There are many different types of wires available for retrograde stent placement (e.g., hydrophilic, hybrid wires, stiff wires). It is preferable to use a wire with a flexible tip to minimize intrarenal injury and risk of bleeding/perforation, especially in the setting of anticoagulated patients. It is also important to ensure that the wire is placed intraluminally rather than submucosally. If significant resistance is encountered during wire placement, the wire should be removed and replaced. Placing a 5Fr catheter over the wire can help confirm that the wire is in the correct position based on lack of resistance and ability to perform a retrograde contrast injection. Placing a wire past an impacted stone may increase the risk of submucosal placement or perforation, and judicious use of a flexible tip catheter, including an angled tip when necessary, monitoring with fluoroscopy, and knowing when to halt attempts at retrograde access can help to reduce these risks.

There is one report of significant intraperitoneal bleeding after stent placement. A patient developed hemorrhagic shock after uneventful stenting, which led to exploratory laparotomy with splenectomy to find and control the source of bleeding, which was intraoperatively identified as a 6-mm renal upper pole puncture. The article emphasized the importance of ensuring the wire is placed correctly with the flexible tip first to avoid trauma from a rigid wire.[30]

If there is significant urinary tract bleeding from mucosal injury/wire trauma, we recommend placing the retrograde stent and monitoring the patient closely. Any bleeding diathesis should be reversed if possible. Continuous bladder irrigation may be needed depending on degree of hematuria.

STENT MIGRATION

Ureteral stents can migrate proximally into the kidney or distally into the bladder (Fig. 21.2). Rates of stent migration reported in literature range from 8% to 9%.[31,32] The etiology is thought to be an incorrectly sized stent (if migration occurs in a delayed fashion) or technical error (during surgery, when the distal end of the stent is pushed too far and becomes intraureteral).

Management includes stent removal and reinsertion for distal migration, and ureteroscopic removal and reinsertion for proximal migration. The latter can be challenging depending on the caliber of the ureter. Several types of graspers and baskets can be used to retrieve the distal end of the stent and to reposition the stent. If this cannot be safely accomplished, "tandem" stenting can be performed to enable ureteral dilation to allow retrieval of the migrated stent at a later point (1–2 weeks).

ADJACENT ORGAN INJURY/STENT EROSION

A rare complication of ureteral stents is erosion into adjacent vascular structures or organs and development of fistulas. Arterio-ureteral fistulas are rare but life threatening. Risk factors include previous cancer surgery/radiotherapy (54%), vascular surgery (31%), and known aneurysm or pseudoaneurysm of the iliac artery (38%).[33] Often, patients present only with massive hematuria. If hemodynamic compromise ensues, mortality rates are reported to be up to 23%, with delayed diagnosis being associated with worsened outcomes.[34,35] Diagnosis can be confirmed with angiography, and management includes a combined approach comprising urology, vascular surgery, and interventional radiology. The preferred approach is stenting of the involved artery; however, options also include ligation, repair, or embolization of the involved vascular structure. The ureter is generally treated conservatively with stenting and/or nephrostomy drainage, and delayed reconstruction may be needed.[33]

Ureteral stents can also erode into the venous system. These events have included erosion and migration via renal, iliac, or ovarian veins into the vena cava and even the right ventricle.[36–38] One patient with a ureteral stent in her right heart had only mild back pain and suprapubic discomfort after voiding.[37] When the stent migrates to the right

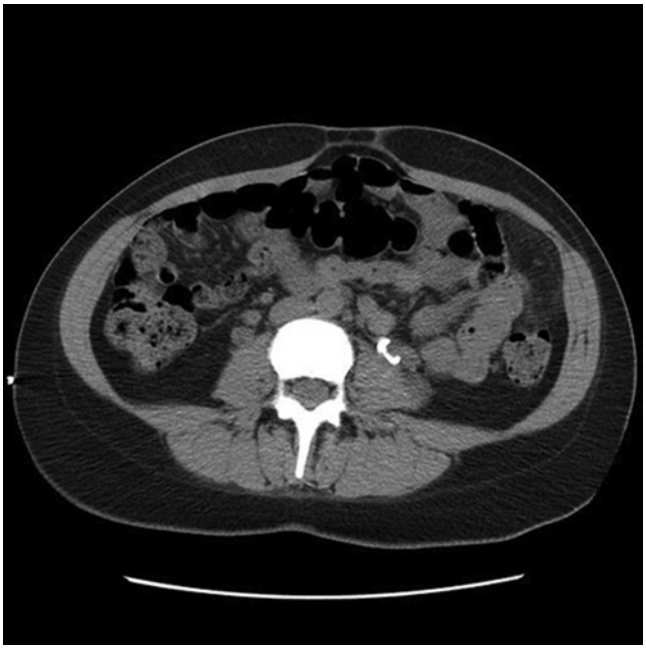


Figure 21.2 DJS with proximal curl in proximal ureter.

ventricle, open heart surgery may be necessary to remove it.[38] When stents are placed into or erode into veins, initially there can be hematuria,[38] or there may be no initial symptoms with large bleeding encountered upon stent removal.[39]

There are reports of stent erosion into adjacent organs, such as the colon[40] or vagina,[41] leading to fistulization. These are very rare events and require stent removal and possible reconstructive surgery. Erosion into the uterus has been reported with antegrade stenting.[42]

STENT ENCRUSTATION

Underlying metabolic conditions, urinary supersaturations, pregnancy, and increased indwelling stent times increase the likelihood of stent encrustation. One study showed encrustation rates of 9.2% at <6 weeks and up to 76.3% at >12 weeks.[43] Another study reported encrustation rates of 26.8% at less than 6 weeks, 56.9% at 6 to 12 weeks, and 75.9% at more than 12 weeks.[44] Encrustation can occur on the distal intravesical portion of the stent, along the intraureteral portion, or on the proximal curl within the renal pelvis. Vigilance regarding the timing of stenting is needed when treating patients who are particularly lithogenic or pregnant, and exchange should occur up to every 4–6 weeks depending on the clinical circumstance.

Diagnosis can be made at the time of cystoscopy, when encrustation is visualized and stent cannot be extracted with the aid of a grasper in the standard transurethral fashion. The diagnosis can also be made using noncontrast CT. Plain x-rays are not recommended, because they may miss minor (but removal-complicating) encrustations.

Attempting to cystoscopically remove an encrusted stent with excessive force can lead to fracturing of the stent or avulsing or intussuscepting the ureter. The management strategies for an encrusted stent therefore include extracorporeal shock wave lithotripsy, cystolithalopaxy, manual scraping of the encrustations from the stent by extraction through a ureteral access sheath, ureteroscopy with intracorporeal lithotripsy, percutaneous nephrolithotomy, and open or laparoscopic pyelolithotomy and/or cystolithotomy. The exact approach depends on burden and the location of encrustation. Often, patients will need more than one procedure.[45–48]

There may be instances in which a stent cannot be removed due to low volume encrustation, and ureteroscopy adjacent to the stent cannot be performed due to narrow anatomy. A second or "tandem" stent can be considered adjacent to the indwelling stent, with staging of the procedure to enable further ureteral dilation and retrograde fragmentation of encrustation in the future.

If a significant ureteral injury occurs during attempted stent removal, such as avulsion or intussusception, a percutaneous nephrostomy tube is generally required with consideration of acute or delayed ureteral reconstruction.

STENT FRAGMENTATION

While stents are designed of sturdy material, there is a risk of stent fragmentation. This may occur from overzealous use of the laser contiguous with the stent or spontaneously.[49] For the former, care in lasing adjacent to an indwelling stent can obviate this issue. The latter is a rare event, but there are published series of spontaneous fragmentation.[49] Plain x-ray, as well as computerized tomography, can diagnose stent fragmentation. It can also be diagnosed at the time of surgery, when an incomplete stent is extracted from the ureter. Management strategies include removal of fragments endoscopically, either retrograde from the bladder or ureter, or percutaneously if needed.

RETAINED STENT

Retained stents can present a significant clinical problem. These stents are at risk for encrustation and can be challenging to remove (see section on encrusted stents for more detail). Retained stents that become encrusted may increase the risk of ureteral injury and can lead to renal atrophy.[48] All patients undergoing stent placement should be counseled that stents are temporary and require exchange or removal to avoid complications. This information should also be provided in paper form for counseling and medicolegal reasons. Stent registries have been used to track patients to reduce the likelihood of retained stents.[50] There are various formats of stent registries in use, ranging from manual handwritten "card" systems, computer based with automatic reminders to providers, to even automatic letter and cellular phone texting reminders to patients.[50–52]

INADEQUATE RELIEF OF OBSTRUCTION/HYDRONEPHROSIS

Ureteral stents may not adequately relieve obstruction, whether the primary process is benign or malignant. Stent failure rates of up to 6% have been reported for urolithiasis.[32] Stent failure rates are greater, however, with malignant extrinsic obstruction, with obstruction rates as high as 44% within 30 days[53,54] and 58% with longer follow-up.[55] Stent failure can be diagnosed by increased hydronephrosis, worsened kidney function despite absent other causes, or clinical suspicion. Management may include stent exchange and monitoring, placement of tandem stents, placement of a metallic stent that can be more resistant to extrinsic compression, or more proximal diversion (percutaneous nephrostomy tube placement). Benign extrinsic compression (e.g., retroperitoneal fibrosis) can also lead to stent failure.

METAL STENTS

When conventional ureteral stents fail, metal stents have been used for long-term drainage in an effort to avoid percutaneous nephrostomy tubes and improve the patient's quality of life. Compared to polymeric ureteral stents, metal stents preserve patency under a greater degree of extrinsic compression and have longer indwelling times necessitating fewer stent changes (up to 12 months). However, they are associated with a high rate of migration (up to 81%), stone encrustation (23%), and obstruction resulting from hyperplastic reaction (up to 60%).[56,57] Tumor ingrowth has also been reported. Metal stents are used mostly for malignant obstruction. One small study reported 100% patency rate (mean follow-up 8.5 months) in patients with malignant obstruction, but only 44% with benign obstruction.[58] A study with longer follow-up (median 15

months) reported 62% patency rate for malignant obstruction.[59] Retrospective studies have shown that metallic stents may not perform better than regular stents in preventing obstruction, particularly in patients with locally invasive prostate cancer;[60] however, there are insufficient data to draw a definitive conclusion. The higher cost of metallic stents raises the question of cost-effectiveness, which requires additional investigation.

Complications of Nephrostomy Tubes

COMPLICATION OF PRONE POSITIONING

Patients undergoing PCN placement are typically placed in a prone position to enable access to the flank. This positioning may be problematic for some patients. For instance, patients with contractures or severe morbid obesity may require modified positioning or additional padding. Ventilatory difficulty for those with severe obesity should be anticipated. For those for whom PCN placement is occurring under sedation, a modified supine position can be used to maintain access to the airway. Prolonged prone positioning should be avoided to prevent neuromusculoskeletal injuries.[61]

TUBE COMPLICATIONS

Urinary leakage around a PCN is uncommon (1%), but may present a hygiene issue.[62,63] First, tube position should be confirmed; this can be done by checking for the presence of urine in the tubing, flushing/aspirating the PCN, or imaging. CT may show the tube in the collecting system, and an antegrade contrast study is most definitive. Skin infection adjacent to the tube is rare as well (1%) and can be treated with oral antibiotics.[62]

Tube dislodgment can be a significant problem. Reported rates of dislodgement range widely from 1% to 36%.[63,64] Pigtail catheters are generally used, and the tube is secured to the skin via permanent sutures and other adherent devices, to reduce the risk of dislodgment. Obesity and precariousness of the tube within the kidney may lead to dislodgment with movement.[62] Replacement of the tube via rewiring or a new access is typically needed.[6]

Catheter occlusion occurs in up to 6% of PCNs and can be managed with irrigation, re-wiring or re-insertion. [62,63] Care must be taken to secure the tubing and drainage bag to a patient's clothing and to avoid excessive traction, both of which are key to avoiding dislodgement.

UTI/SEPSIS

Sepsis can occur following PCN placement due to bacteremia from the procedure, or from incipient urosepsis in the setting of obstruction and infection. The incidence of septic complications with PCN placement is reported as being ~2%, but varies based on the clinical scenario.[64,65] In the setting of pyonephrosis, this incidence rate rises to 7–9%.[66,67] Incidence of symptomatic urinary-tract infection or pyelonephritis ranges from 2.5% to 14%.[63,68] Because the PCN is a foreign body, the incidence of infection increases to 27% in patients with long-term tube placement (at least one PCN change).[68] Changing the PCN every 6–12 weeks for chronic tubes may reduce the risk of clinical infection. Periprocedural prophylaxis with culture-specific antibiotics may decrease the risk of procedure-induced infection.

PLEURAL COMPLICATIONS

Placement of a PCN may be complicated by injury to nearby structures, including the pleura (Fig. 21.3). The incidence of pleural complications (i.e., pneumothorax, empyema, hydrothorax, hemothorax) is reported to be 0.1–0.2%.[67] Patients can exhibit signs of pulmonary compromise or hemodynamic instability (e.g., hemothorax). These complications are diagnosed by imaging (such as chest radiography or CT scan). Management depends on the patient's clinical status. For example, stable patients with small volume pneumothorax/hydrothorax can be managed with observation. For respiratory distress in the setting of a pneumothorax, a pigtail pleural catheter can be placed. If a patient is in more significant distress or there are signs of infection, tube thoracostomy can be used. In severe cases (for example, hemothorax from lacerated intercostal vessels), thoracoscopy or thoracotomy may be required. If pleural infection develops, a large bore chest tube is needed with consultation by thoracic surgery.

HEMORRHAGE, HEMATURIA/CLOT COLIC

Hemorrhage is the most common local complication of PCN placement (Fig. 21.4). Venous bleeding is usually self-limited and stops with tamponade effect. Arterial bleeding is more severe and results most commonly from renal artery branches or intercostal arteries. To minimize the risk of injury to the intercostal arteries, access should be obtained

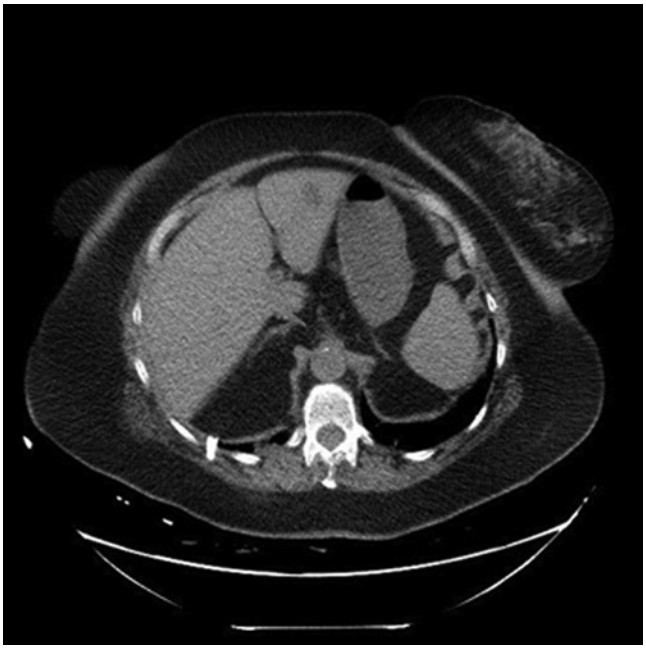


Figure 21.3 Transpleural percutaneous nephrostomy tube.

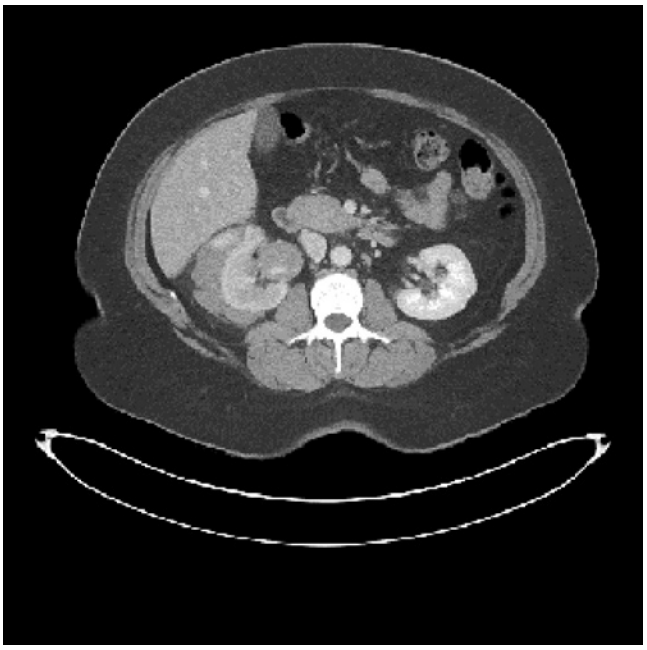


Figure 21.4 Perirenal hematoma and extravasation after unsuccessful percutaneous nephrostomy tube placement.

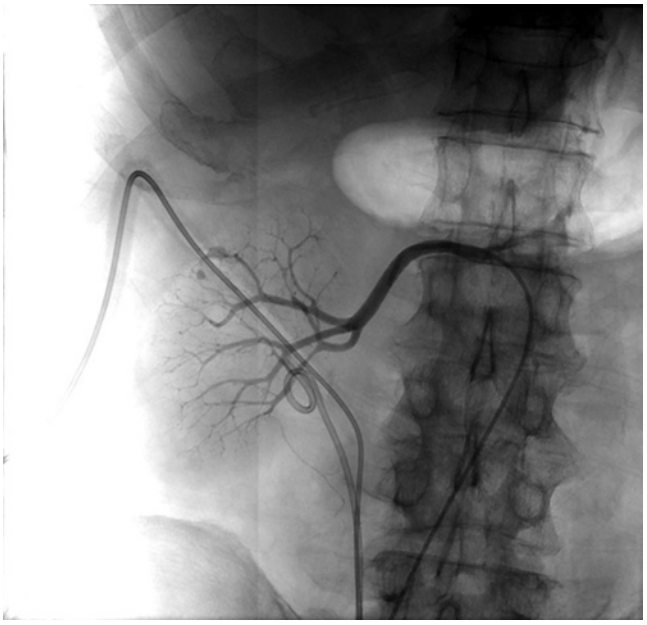


Figure 21.5 Renal arterial angiogram demonstrating pseudoaneurysm at site of nephroureteral stent.

directly above the rib and in the avascular Brodel's line on the posterolateral kidney. Entry to the collecting system should occur at a calyx rather than the infundibulum. Arterial injury can lead to hematoma, pseudoaneurysm (Fig. 21.5), or a fistula. Hematuria causing clot colic and catheter blockage occurs in 0.5–6.5% of patients.[64] Hemorrhage requiring transfusion occurs in 0.5–4% of patients.[64,65,68] Vascular injury necessitating embolization or nephrectomy is reported in 0.1–1% of patients.[63,67] Severe persistent gross hematuria or perinephric hemorrhage related to arterial bleeding associated with hemodynamic changes requires selective angioembolization as the first-line intervention.

If there is profuse bleeding from the nephrostomy tract refractory to tamponade from the PCN, a Kaye tamponade catheter can be placed in the tract and balloon inflated for additional tamponade effect. This may be therapeutic or temporizing until further management. If the bleeding is severe, or in the case of arteriovenous fistulas, first-line treatment involves selective renal artery embolization.[69] This allows for nephron preservation, compared to nephrectomy. Nephrectomy is the option of last resort for refractory bleeding.

URINE LEAK/RENAL PELVIS PERFORATION

Renal pelvic injuries can occur during tract dilatation or catheter insertion in 1–2% of cases.[62,70] This may lead to perinephric urinoma formation. Treatment is usually continued renal drainage only (via properly positioned PCN and/or indwelling stent). Surgical correction is rarely needed, but may be necessary if the injury is severe or shows no evidence of healing after 6 weeks.[70] Ensuring the absence of a foreign body, such as the PCN abutting or protruding through the fistulous tract, is necessary to ensure healing occurs.

One study reported asymptomatic retroperitoneal urine extravasation at a rate of between 4.5% and 6.5%.[64] This usually reabsorbs and is treated with urinary tract drainage and observation.

INJURY TO INTRAABDOMINAL ORGANS

Other organs that may be injured during percutaneous access include liver, gallbladder, bowel, and the spleen. Bowel injury is the most common intraabdominal injury and occurs in 0.2%[67] to 0.5%[64] of PCN placements. The colon is the most frequently injured portion of the bowel, though small bowel (e.g., duodenum) injury is also possible.[71] Jejunal injuries have been reported as complications of nephrolithotomy, but not nephrostomy itself.[72] Small bowel injury from PCN may lead to small bowel obstruction,[73] though the complication of greatest concern is perforation. Timely diagnosis is crucial. Signs and symptoms of bowel injury include pneumaturia, fecaluria, fever, diarrhea, hematochezia, and peritonitis. If bowel perforation is intraperitoneal, surgical repair is required. If the perforation is extraperitoneal and the patient is stable, the injury may be treated conservatively.[74,75] Also, if access to the colon is inadvertently performed without extravasation, this should be treated conservatively. Conservative treatment entails a ureteral stent and Foley catheter (or a second percutaneous nephrostomy tube) to drain the urinary tract and positioning of the original nephrostomy tube into the colonic lumen.[75] After 7–10 days, contrast is injected to verify no communication between the colonic tube and the urinary tract, and the colon tube can then be safely removed.

TUMOR SEEDING

Tumor seeding is a rare complication of percutaneous drainage in patients with high-grade urothelial cancer,

with several case reports in the literature.[76,77] Careful access to minimize trauma and number of accesses to the kidney can help to reduce the risk of this complication. Retrograde access is preferred when feasible for this disease process to reduce the likelihood of seeding.

Complications of Antegrade Stents

Some patients require antegrade placement of a DJS, for example, based on inability to place one in retrograde fashion or after a percutaneous procedure. Antegrade stenting can be done as a one-stage or two-stage procedure (with initial establishment of percutaneous access). One-stage tubeless PCNs have been described to have an 88% success rate;[78] however, the majority of antegrade stenting is done in a two-stage fashion.[42]

Overall, complications of antegrade stent placement are similar to those of retrograde stenting. There is a single report of ureterovaginal fistulization during antegrade stent placement that results from a silent ureteral perforation. Rao et al. reported ureteral perforation with unrecognized extra-anatomic stent placement in 3% of antegrade stent attempts, all with delayed manifestations (retroperitoneal abscess, urinoma, ureterorectal fistula, ureterovaginal fistula).[42]

Conclusion

Upper tract drainage can be achieved by multiple ways: percutaneous nephrostomy, retrograde or antegrade stenting. All three methods are generally safe, and effective in the appropriate patient. Complications may occur, but can be minimized with careful technique, proper patient selection, and early recognition.

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Chapter 21 Questions

1. In order to avoid the intercostal vessels, percutaneous nephrostomy access should be obtained:
   a. Between the ribs in Brodel's line
   b. Directly above the rib in the posterolateral kidney
   c. Directly below the rib in the posterolateral kidney
   d. Directly above the rib in the posteromedial kidney
   e. 0.5 cm below the rib in the posteromedial kidney

2. One day after nephrostomy tube placement, the patient presents with abdominal pain and gas in his nephrostomy tube. He is afebrile and hemodynamically stable. CT scan reveals an extraperitoneal colonic perforation. The management is:
   a. Exploratory laparotomy with perforation repair
   b. Repositioning of the tube into the colon
   c. Ureteral stent, Foley, and repositioning of the tube into the colon
   d. Ureteral stent, Foley catheter, and removal of the nephrostomy tube
   e. Removal of the nephrostomy tube followed by perforation repair

3. Three days after left ureteroscopy with laser lithotripsy, the ureteral stent is uneventfully removed in clinic. Two days later the patient presents with left back and abdominal pain, ileus, and fevers to 102.5°F. A CT scan is done that shows a large periureteral collection. The next step in management is antibiotics and:
   a. Left percutaneous nephrostomy tube
   b. Left ureteral stent
   c. Left percutaneous nephrostomy tube and left ureteral stent
   d. Percutaneous drain
   e. Percutaneous drain and left ureteral stent

4. A ureteral stent was placed for unilateral hydronephrosis; however, during the procedure it was pushed too far into the ureter and it is no longer visible in the bladder. The ureter is too narrow to accommodate a ureteroscope. What is the next step?
   a. Using a piranha grasper to retrieve the distal end
   b. Using a ureteral dilator to dilate the ureter to enable access to the migrated stent
   c. Percutaneous nephrostomy tube, with antegrade stent retrieval on the same day
   d. Percutaneous nephrostomy tube, with antegrade stent retrieval in 1 week
   e. Tandem stent, followed by return to the operating room in 1 week to retrieve the stent

5. Shortly after left PCN placement, a 56-year-old male develops shortness of breath. His vitals signs are: T 36.5°C, HR 120, BP 115/67, saturation 80% on room air. The saturation increases to 86% with 10L nasal cannula. In addition to applying more oxygen, what is the next step?
   a. Observation
   b. Chest x-ray followed by tube thoracostomy
   c. CT chest angiography
   d. Transfusion of 1 unit of blood and chest CT
   e. Removal of nephrostomy tube and placement of occlusive dressing over the site

6. A 69-year-old female has bilateral ureteral obstruction caused by ovarian cancer, which has been managed with indwelling polymeric ureteral stents. The stents get exchanged every 3 months, with minimal encrustation. They were last changed 30 days ago. Today, she presents to the hospital with creatinine increase (from 1.5 to 2.6), and right-sided flank pain. A CT scan reveals both stents in appropriate position, moderate hydronephrosis on the left, severe hydronephrosis on the right, and increase in size of her pelvic mass. The patient is scheduled to start chemotherapy the next day. What is the next step in her urologic management?
   a. Bilateral ureteral stent exchange for polymeric stents
   b. Bilateral ureteral stent exchange for metallic stents
   c. Right PCN tube
   d. Left metallic stent and right PCN tube
   e. Bilateral PCNs

7. A 45-year-old woman with unilateral retroperitoneal fibrosis managed with right-sided ureteral stent exchanged every 6 months has been lost to follow-up for 14 months. Abdominal x-ray reveals the stent in the appropriate position, with no encrustations visible on the x-ray. The patient should be scheduled for the following:
   a. Extracorporeal shock wave lithotripsy
   b. Routine cystoscopy with stent exchange
   c. Cystoscopy with stent exchange, possible ureteroscopy with laser lithotripsy, and possibility of a staged procedure
   d. Ureteroscopy with laser lithotripsy, with possibility of a staged procedure
   e. CT scan of the abdomen and pelvis

8. Risk factors for urinary tract infection with chronic ureteral stents include:
   a. Increased duration of stent retention, chronic renal failure, male gender
   b. Female gender, diabetes mellitus, chronic renal failure
   c. Increased duration of stent retention, obesity, diabetes mellitus
   d. Diabetic nephropathy, dialysis, age >65
   e. Female gender, age >65, obesity, chronic renal failure

9. The following ureteral stent positions have been shown to exacerbate stent symptoms:
   a. Incomplete distal curl
   b. Distal curl crossing the midline of the bladder
   c. Proximal curl in the upper pole
   d. a, b, and c
   e. a and b

10. During ureteroscopy for a 5-mm distal ureteral stone, significant resistance is encountered in the midureter with a guidewire. The next step is:
    a. Removing and replacing the wire
    b. Removing the wire, turning it around, and using the back stiffer end
    c. Placing a 5Fr open-ended catheter over the wire and performing a retrograde contrast injection
    d. a or b
    e. a or c

Case Study 1

A 53-year-old man presents to the ED with 3 days of fever and back pain. He reports a history of poorly controlled diabetes, hypertension, and kidney stones. His temperature is 38.3°C, heart rate is 110, blood pressure is 90/50, and respiratory rate is 20. On exam, he is diaphoretic and ill-appearing. He has right costovertebral angle tenderness. His labs show WBC 22 and a serum creatinine of 2.4. He is given resuscitative fluids, and a noncontrast CT scan is obtained that reveals a 2.9-cm right renal pelvis stone with severe hydronephrosis and perirenal stranding.

1. What is the next step in management?
    a. Admit for broad-spectrum antibiotics and observation
    b. Percutaneous nephrostomy tube placement
    c. Retrograde ureteral stent placement
    d. Antegrade ureteral stent placement
    e. Percutaneous nephrolithotomy

He undergoes percutaneous nephrostomy tube placement and improves clinically. Urine and blood cultures grow *Escherichia coli* and he is placed on culture-specific antibiotics. Three weeks later, he is brought to the OR for PCNL. This is uncomplicated; however, in the PACU gross blood begins to drain from the nephrostomy tube, and the patient is noted to be hypotensive to 80/30.

2. What is the next step in management?
    a. Send a CBC
    b. Monitor vital signs continuously
    c. Send to interventional radiology for angioembolization
    d. Clamp the nephrostomy tube
    e. Return to operating room for exploration

The patient stabilizes, and a hemoglobin returns with a value of 7.5. The patient is given 2 units of packed red blood cells (PRBC). However, he develops recurrent hypotension and his repeat hemoglobin is 7.9.

3. What is the next step in management?
    a. Repeat transfusion of 2 units PRBC
    b. Admit to the ICU for monitoring
    c. Angioembolization
    d. Emergent nephrectomy
    e. Remove the nephrostomy tube

Case Study 2

A 43-year-old woman presents to the ED with abdominal pain. She has a history of kidney stones. Her pain radiates to the right groin. She denies fever or chills. She is afebrile with stable vital signs. Her exam shows some sensitivity on the right flank. She appears uncomfortable. A noncontrast CT scan shows a 3-mm proximal ureteral stone with proximal collecting system dilation. Her labs are normal with a serum creatinine of 1.0. She elects for a trial of passage, but on follow-up she continues to have pain and a renal ultrasound shows persistent hydronephrosis. She is brought to the OR for ureteroscopic management. Cystoscopy is performed, and a hybrid guidewire is advanced through the ureteral orifice with fluoroscopic guidance. The wire will not traverse the area of the known stone and buckles underneath.

1. What is the next step in management?
    a. Wake the patient and send for a percutaneous nephrostomy tube
    b. Perform ureteroscopy without a safety wire
    c. Wake the patient and refer for shock wave lithotripsy
    d. Use an angle-tip hydrophilic guidewire to traverse the stone
    e. Use the stiffer (back) end of the Sensor wire to traverse the stone

The angle-tip wire is also unable to traverse the area of stone. A retrograde pyelogram is performed that shows the following (Case Fig. 21.1):

2. What is the next step in management?
    a. Wake the patient and send for a percutaneous nephrostomy tube
    b. Perform ureteroscopy without a safety wire
    c. Wake the patient and refer for shock wave lithotripsy
    d. Place a periureteral drain
    e. Use the stiff (back) end of the wire



Case Figure 21.1

The patient obtains a percutaneous nephrostomy tube. Two weeks later, she is brought for ureteroscopy, which is uncomplicated. A double J stent is placed and the nephrostomy tube is removed. She returns to the ED that night with severe flank pain. She has no fever and has stable vital signs.

3. What is the next step in management?
   a. Give Flomax and oral narcotics for symptom control
   b. Give antibiotics for presumed pyelonephritis
   c. Reassurance
   d. CT scan with IV contrast
   e. KUB to confirm adequate position of the stent

Answers

1. **b.** To avoid intercostal vessels, obtain access directly above the rib in Brodel's avascular line (posterolateral kidney).
2. **c.** Since the patient is hemodynamically stable, he can be managed conservatively with ureteral stent, Foley catheter and repositioning of the tube into the colon. If he was unstable, or if the perforation was intraperitoneal, then the perforation would need to be repaired.
3. **e.** The patient had a ureteral perforation with urinary extravasation that became infected; he requires both a ureteral stent (to encourage antegrade urine flow and buttress the injured ureter), as well as a percutaneous drain of the infected collection.
4. **e.** In the case of proximal migration of a ureteral stent, the end can be grasped with a basket or grasper to try to retrieve and reposition the stent. However, in this case, since the ureter is too narrow to accommodate the ureteroscope, tandem stenting should be used to decompress and enable passive dilation of the ureter.
5. **b.** The patient likely has a pleural complication. The next step is imaging (to distinguish between the different types of pleural complications). Given patient's respiratory distress, he will need a tube thoracostomy after imaging.
6. **e.** The patient's ureteral stents have failed in the setting of enlarging pelvic mass. Given her rise in creatinine, she needs bilateral PCNs to help maximize renal function.
7. **c.** Imaging is not reliable in predicting the ease of removal of a retained stent. Although no encrustations are visible on imaging, the stent may still be encrusted, and patient should be counselled accordingly about possible need for ureteroscopy with laser lithotripsy and possibility of a staged procedure.
8. **b.** The risk factors for urinary tract infection with chronic ureteral stents are the following: female gender, diabetes mellitus, chronic renal failure, diabetic nephropathy and longer duration of stent retention.
9. **e.** Stent positions that exacerbate stent symptoms are the following: incomplete distal curl, distal curl crossing the midline of the bladder and proximal curls located in a calyx.
10. **e.** When significant resistance is encountered, the wire can either be removed or replaced, or a retrograde contrast injection can be performed. Never use the back (stiff) end of a wire, as this can lead to perforation.

CASE STUDY 1

1. **b.** Patient is presenting with urosepsis and needs emergent decompression. PCN is the preferred option given patient's hemodynamic instability. If interventional radiology is unavailable, retrograde ureteral stent can also be attempted. Antegrade ureteral stent is not appropriate in this scenario. Percutaneous nephrolithotomy will likely be necessary in the future given large stone burden.
2. **d.** The patient is actively bleeding. The first step is to "apply pressure", in this case clamp the nephrostomy tube that is draining gross blood. Only then should a CBC be sent and vital signs monitored.
3. **c.** The patient has persistent bleeding. He will likely require more blood products, and possibly a higher level of care (such as the ICU), however the most important step is trying to control the source of bleeding with angioembolization. Nephrectomy is used if angioembolization fails. Removing the nephrostomy tube will likely only exacerbate the bleeding.

CASE STUDY 2

1. **d.** The first step is using a glide-wire. Never use the stiff back end of a wire, this will increase the risk of ureteral perforation. If the area cannot be traversed with a glide-wire, then a percutaneous nephrostomy can be discussed with patient. The stone is likely too small for shockwave lithotripsy. Ureteroscopy without a safety wire in the setting of impacted stone is not recommended.
2. **a.** The figure shows contrast extravasation after attempted wire placement. The wire was never able to traverse the stone. The next step is placement of a percutaneous nephrostomy tube. Ureteroscopy without a wire is contraindicated especially in the setting of a perforation. Never use the stiff back end of a wire, this will only exacerbate the ureteral perforation.
3. **e.** Reassurance, Flomax and oral narcotics should be used only after adequate position of the stent is confirmed. This can be done with KUB, renal US, or a non-contrast CT scan. Pyelonephritis is unlikely given lack of fevers.

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22 Complications of Intravesical Therapy

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CHAPTER OUTLINE

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KEY POINTS

1. The local and systemic inflammatory toxicities of bacille Calmette-Guérin (BCG) are usually short-lived and can be managed symptomatically.
2. Prevention of systemic absorption and infectious toxicity of BCG relies on healing of the bladder wall and avoidance of trauma at the time of instillation.
3. Prompt recognition and treatment of BCG sepsis is essential, given its potential for mortality.
4. Mitomycin C (MMC) is the least likely absorbed intravesical chemotherapeutic agent, given its molecular weight.
5. Toxicity of MMC is usually related to irritation of the bladder and resolves with time. Nonetheless, instillation should be avoided in the setting of bladder perforation, large resection defects, or ureteral orifice resection.
6. Although MMC is frequently given perioperatively, BCG should not be given until bladder wall healing is achieved following transurethral resection.
7. Valrubicin and gemcitabine are newer agents with efficacy in BCG-refractory disease and mild toxicity profiles primarily limited to local, irritative symptoms.

Nearly 80% of newly diagnosed bladder cancers represent nonmuscle invasive urothelial carcinoma (i.e., stage Ta, stage T1, or carcinoma in situ [CIS]).[1] Numerous intravesical agents may be used in the management of these cancers. Thus, specific knowledge of the toxicity of these agents is imperative for the practicing urologist.

Intravesical Immunotherapy

BACILLE CALMETTE-GUÉRIN

Bacille Calmette-Guérin (BCG) is used for patients with stage T1 tumors, CIS, or stage Ta tumors of high grade. Originally introduced for this indication by Morales and colleagues in 1976, BCG is now accepted as the most efficacious of the intravesical agents.[2–4] Numerous studies demonstrate that the use of BCG reduces the risk of disease recurrence and progression.[5–8]

BCG's mechanism of action involves creating an inflammatory reaction in the bladder by means of live, attenuated mycobacteria.[9–12] For this reason, the rate of local side and systemic side effects is high. The primary cytokines released following intravesical BCG administration are interferon-γ (IFN-γ) and interleukin 2 (IL-2); therefore, many of the systemic side effects noted with BCG are similar to those seen with the systemic administration of cytokines.[13,14] The primary cytokine-related side effects of BCG often do not occur until the third or fourth instillation, a finding suggesting cumulative cytokine release with increasing exposure to the antigen.

Traditionally, BCG was given in 6 weekly instillations, although numerous studies indicate a significant benefit

from maintenance therapy as opposed to induction therapy alone.[15–17] The largest of these studies was the Southwest Oncology Group (SWOG) trial, which randomized 550 patients with recurrent Ta, T1, or CIS to receive either induction alone or induction and maintenance using 3-week treatments given at 3, 6, 12, 18, 30, and 36 months. Median time to disease recurrence was 35.7 months in the group without maintenance and 76.8 months in the maintenance group. At 5 years, the recurrence-free rate was 41% and 60%, respectively.[15] Maintenance therapy, however, was not well tolerated; only 16% of the 243 patients completed all eight scheduled maintenance courses over 3 years.

Low-dose BCG was proposed as a means of decreasing toxicity and improving tolerance.[18–20] A large randomized trial compared 500 patients treated with a BCG dose of either 27 mg (1/3 dose) or 81 mg and found no statistically significant difference in recurrence or progression between the two groups.[18] The investigators reported a significant reduction in toxicity in the low-dose group. A subsequent study from the same group demonstrated that BCG 27 mg (1/3 dose) is superior to BCG 13.5 mg (1/6 dose) with regards to disease recurrence and equivalent with regards to side effects.[20]

A shorter duration of maintenance therapy has been suggested as another approach to reduce BCG toxicity.[21,22] A noninferiority, randomized study of 1355 patients compared 1/3-dose BCG with full-dose BCG and 1 year of maintenance with 3 years of maintenance therapy using a primary outcome of disease recurrence.[21] One-third–dose BCG was not found to be inferior to full-dose BCG. In high-risk patients (i.e., T1 or grade 3), 3 years of maintenance with full-dose BCG reduced disease recurrence as compared to 1 year of maintenance with full-dose BCG, but there was no difference in disease progression or survival. This benefit from 2 additional years of maintenance with full-dose BCG was not observed in intermediate-risk patients. There was no significant difference in toxicity by either reducing the dose or the duration of maintenance.[22]

Numerous strains of BCG are widely used: TICE, Connaught, RIVM, Armand Frappier, Pasteur, and Tokyo. In a large meta-analysis, Lamm and colleagues found no difference among the different strains in terms of clinical efficacy or side effects.[14] Other studies have suggested that efficacy varies with strain, but there is currently insufficient evidence for specific recommendations.[2,3,23]

OVERVIEW OF COMPLICATIONS

Although BCG is generally well tolerated, every urologist should be familiar with the expected and unexpected adverse effects. Soloway and associates reviewed 234 patients referred from community urologists and found significant numbers of patients treated for Ta G1 disease, a pathologic stage and grade in which one must seriously consider whether the side effects of BCG outweigh the small benefit in treatment of typically indolent disease.[24]

A distinction should be made between expected side effects and true complications of BCG therapy (Table 22.1). Local and systemic toxicities can be divided into immune-mediated or infection-mediated complications. Local toxicities are generally treatable and unavoidable symptoms. Some degree of local toxicity is experienced by virtually all patients, although the reported incidence in contemporary series ranged from 27% to 90% depending on sample size,

Table 22.1 Frequency of Bacille Calmette-Guérin Complications

Study (year)	No. Patients	Induction Dose	Maintenance Dose	Irritative Voiding Symptoms	Fever	Sepsis	Death
Pagano et al (1991)[118]	126	75 mg Pasteur, 6 wk	Monthly × 1 yr, every 4 mo × 1 yr	30%	17%	0%	0%
Lamm et al (1992)[28]	2602	50 mg, 6 wk		90%	2.9%	0.4%	0%
Witjes et al (1993)[25]	140	TICE 5 × 108 CFU/50 mL, 6 wk	3 and 6 mo, 6 weekly treatments if recurrence	30%	2%	0.71%	0%
Martinez- et al (1990)[119]	252 248	Connaught, 81 mg/50 mL, 6 wk Connaught, 27 mg/50 mL, 6 wk	6 instillations every 2 wk	71% 62%	2% 2%	0% 0%	0% 0%
Vegt et al (1997)[26]	290	50 mg, 6 wk	3 weekly instillations at 3, 6, 12, 18, 24, 30, 36 mo	53%	11%	0%	0%
Bassi et al (1999)	126	Pasteur 75 mg	Monthly × 1 yr, every 4 mo × 1 yr	27%	17%	0%	0%
Iori et al (2002)[120]	41	TICE 5 × 108 CFU/50 mL	Monthly × 11, every 3 mo × 4, every 6 mo × 6	68%	2.4%	0%	0%
Kolodziej et al (2002)[121]	102	TICE 5 × 108 CFU/50 mL, 6 wk	3 weekly instillations at 3, 6, 12, 18, 30, 36 mo	84%	13%	?	0%
Gontero et al (2013)[116]	57	Connaught, 27 mg/50 mL, 6 wk	3 weekly instillations at 3, 6, 12 mo	36.8%	17.5%	0%	0%
Brausi et al (2014)[22]	1316	TICE 5 × 10^8 CFU/50 mL, 6 wk TICE 5 × 10^8 CFU/150 mL, 6 wk	3 weekly instillations at 3, 6, 12 +/– 18, 24, 30, 36 mo	63%	8.1%	0.3%	0%

dose and regimen, and definition of local toxicity.[14,25,26] Although many investigators believe that a strong correlation exists between BCG toxicity and efficacy, this link has never been proven in clinical trials.[27]

Systemic complications are uncommon, and >95% of patients will tolerate the treatment well. In a review of 2400 cases, Lamm and colleagues found that fever >103°F was the most severe adverse event (2.9%).[28] Other systemic complications include granulomatous changes, sepsis, pneumonitis, hepatitis, arthralgias, and cutaneous manifestations. Although major adverse reactions are unusual, it is important that the urologist recognize, diagnose, and treat these conditions early. When these complications are diagnosed and treated appropriately, virtually all patients recover from them with no long-term sequelae.

In an attempt to reduce side effects and improve tolerability, isoniazid (INH) has been tested as a prophylactic adjunctive treatment with BCG. A study by Vegt and associates did not show any reduction in local or systemic reactions when INH was used prophylactically.[26] In addition to not providing any protection against reactions to BCG, INH was associated with a significantly higher risk of developing abnormal hepatic transaminase levels. More recently, ofloxacin was given in a randomized multicenter trial to 115 patients undergoing BCG treatment.[29] Prophylactic ofloxacin was found to decrease the incidence of moderate-to-severe adverse events, which many investigators believe cause patients to discontinue treatment. No negative effect on efficacy was reported in the ofloxacin-treated group.

SPECIFIC COMPLICATIONS

We generally categorize the side effects of BCG as local, inflammatory, or infectious. Management and prevention of these side effects depend on the timing of BCG administration and the early recognition of symptoms.

Local Toxicity

The most commonly seen local toxicity of BCG is cystitis-like irritative voiding symptoms, reported in ≤90% of patients.[30,31] Severe symptoms typically occur after the third instillation when lymphokine release causes the maximal inflammatory response. Consideration should always be given to secondary bacterial infection, and a negative urine culture should be obtained before further BCG administration. If a urinary tract infection (UTI) is present, it should be treated and BCG should be delayed until 1 week after resolution of the infection.[32]

Most local symptoms subside within 2 to 3 days of administration, but in severe cases, symptoms can persist for several weeks after completion of therapy. Management should include local analgesics such as phenazopyridine and anticholinergics if severe bladder overactivity is noted.[32] However, further study regarding anticholinergics is required, as a recent randomized study did not demonstrate improvement in urinary symptoms with oxybutynin.[33] BCG dose reduction may be considered on follow-up administration, but unless the problem is severe, doses should not be withheld on the basis of local irritative symptoms alone. These patients may also benefit from treatment with quinolones, though it is unclear if quinolones will reduce further efficacy. Ofloxacin 200 mg given twice after each BCG instillation was found to reduce toxicity and improve compliance with BCG therapy. Antituberculosis therapy (e.g., isoniazid, rifampin) has not demonstrated efficacy in the prophylactic setting. We have generally avoided quinolones during BCG administration, and monitored urine cultures on a routine basis to determine the need for antibiotic therapy.

Gross hematuria occurs in 1–34% of patients receiving BCG.[31,34] It is usually self-limiting and most commonly occurs after the second or third dose. Urine culture should be obtained. Further BCG administration should be delayed until resolution of hematuria.[32] If hematuria does not resolve after 2 to 3 weeks of observation, repeat cystoscopy is indicated to exclude the possibility of recurrent tumor.

Inflammatory Toxicity

Flulike symptoms, such as low-grade fever <101.3°F, often accompany the irritative voiding symptoms. Malaise, myalgia, and low-grade fever typically last 24 to 48 hours. Treatment with acetaminophen and nonsteroidal antiinflammatory drugs (NSAIDs) is typically successful. In many cases, we have used prophylactic acetaminophen administered at the time of BCG instillation if patients have previously demonstrated such toxicity upon administration. In our experience, the likelihood of inflammatory toxicity may increase with increasing exposure to BCG, and it is rare for patients to have substantial symptoms within the first few doses of induction. Over time, if administered as maintenance therapy, inflammatory toxicity may increase, and dose reduction can be an effective strategy when symptoms become severe. If no resolution is noted after 48 hours, or symptoms are severe and refractory to simple maneuvers, consideration should be given to antituberculosis therapy with two or more agents until symptoms resolve.[32]

Infectious Toxicity

High fever (>102–103°F) or shaking chills suggests fever resulting from systemic absorption and warrants empiric treatment with antituberculosis therapy. Failure to treat or delay in diagnosis can result in a progression to sepsis and mortality.

Sepsis typically occurs in <4% of patients.[31] In patients who develop BCG sepsis, therapy must be immediate and aggressive. More than 10 deaths have been attributed to BCG sepsis, and the rate is estimated to be 1 death for every 12,500 patients treated with intravesical BCG. The classic presentation is a patient with history of traumatic catheterization who presents with fever, chills, hypotension, and mental confusion. Respiratory failure, hepatomegaly, jaundice, leukopenia, and disseminated intravascular coagulopathy can occur. Although BCG sepsis generally occurs soon after instillation, a delayed onset several months after BCG therapy is possible. Results of culture are typically negative for mycobacteria, and treatment must be started based on clinical suspicion.

Management includes cessation of intravesical BCG, consultation with an infectious disease specialist, and administration of INH, rifampin, ethambutol, fluoroquinolones, and high-dose corticosteroids.[32] Empiric coverage of gram-negative organisms and/or *Enterococcus* can also be considered. Lamm proposed that BCG sepsis is, in part, the result of a delayed-type hypersensitivity reaction, and

for this reason the administration of 40 mg prednisolone may improve survival.[34] Whereas corticosteroids and fluoroquinolones may be discontinued after the resolution of symptoms, antituberculosis agents should be continued for a minimum of 6 months. Addition of a fourth antituberculosis drug can be considered in severe cases. Of note, BCG strains are not sensitive to pyrazinamide. The use of cycloserine has previously been proposed by some investigators for systemic BCG absorption. Although the use of this agent has shown a survival advantage in mice, it appears to be ineffective against currently used BCG strains and thus is not recommended.[35–37]

Prevention of Systemic Absorption

Numerous factors may contribute to the risk of systemic absorption. Most commonly, traumatic catheterization, a nonhealing resection site, and unrecognized UTI are the leading suspects.

During catheterization of a patient for BCG instillations, any difficulty or trauma should raise concern. At least seven reported deaths have resulted from systemic BCG infection after traumatic catheterization.[31] At the time of instillation, atraumatic catheterization is essential. If traumatic catheterization does occur, BCG therapy should be withheld for 1 week.[32] A history of significant urethral stricture may be a contraindication to BCG therapy. In these patients, the stricture disease should be treated definitively prior to initiating intravesical therapy.

On rare occasions, a patient can be treated with a catheter in place. Following catheterization, the BCG is instilled and the catheter is left capped for 2 to 3 hours, depending on the patient's bladder capacity. Caution must be exercised to ensure that the patient does not have poor compliance or detrusor instability, which may result in high intravesical pressure and systemic absorption. Such individuals may not be appropriate candidates for BCG therapy if they also have poor bladder capacity. BCG should not be administered in the setting of known muscle-invasive or necrotic bladder cancer.

BCG instillation should be performed by gravity, not by pressurized instillation. Generally, a syringe with the piston removed can be attached to the catheter and used as a reservoir for gravity-driven instillation.

Following tumor resection, it is recommended to withhold BCG for 2 weeks.[32] We have found an interval of 2 to 3 weeks with resolution of hematuria is usually sufficient to allow healing without affecting therapeutic outcome. In patients with a large resection bed, flexible cystoscopy can be used to ensure healing, and the presence of residual tumor, before BCG instillation. Gross hematuria or significant microscopic hematuria should have resolved before instillation. Periodic urine culture is useful to identify UTI. Symptoms alone may not be helpful for identification of UTI because most patients experience some irritative voiding symptoms.

Granulomatous Complications

Granulomatous prostatitis is reported to occur in 1–27% of patients receiving BCG therapy, depending to some degree on the treatment regimen.[31] The true incidence of this complication is likely much higher and was found to be as high as 40% among patients undergoing biopsy in one study.[38] Granulomatous prostatitis is usually discovered incidentally on digital rectal examination in patients with or without an elevated prostate-specific antigen (PSA) level. In the small percentage of patients who are symptomatic (6%), Lamm and associates noted that these patients usually present with acute prostatitis or urinary retention.[39] Biopsy is needed to rule out cancer, and once the diagnosis is made, asymptomatic patients can be observed. Symptomatic disease warrants cessation of BCG instillations and treatment with INH 300 mg/day and rifampin 600 mg/day for 3 to 6 months and high-dose fluoroquinolones and corticosteroids until symptoms resolve.[32,37,40]

It is wise to obtain a PSA level before BCG therapy. This test should be performed at a time distant from lower tract instrumentation. If test results are normal, PSA need not be measured until 1 year following BCG instillation. In individuals undergoing maintenance therapy, we determine the PSA level immediately before the 12-month maintenance dose. Prostate nodules and elevated PSA are common in men undergoing BCG therapy. Given the frequent instrumentation, rises in PSA level are difficult to interpret. We have found multiparametric prostate MRI to be invaluable in this setting as it often distinguishes between inflammation, BCG granuloma, or regions suspicious for prostate cancer. One may give a course of INH for 2 to 3 months to assess the cause of PSA elevation. If the BCG treatment was given in the remote past, the urologist should proceed directly to biopsy on the basis of PSA or abnormal exam.

More infrequently, granulomatous epididymo-orchitis or even granulomatous balanoposthitis can occur.[41] Patients with granulomatous epididymo-orchitis generally present with local induration and pain. Local symptoms may be accompanied by fever or leukocytosis. A diagnosis of bacterial infection should be excluded, as epididymo-orchitis in the setting of BCG therapy is often caused by gram-negative bacteria.[32] Treatment is with INH and rifampin for 3 to 6 months and fluoroquinolones and steroids until symptoms resolve. Some cases may proceed to abscess formation requiring orchiectomy for definitive treatment. Granulomatous balanitis can present with erythematous nodules on the glans and should be treated with antituberculosis therapy.[37]

Granulomatous hepatitis and pneumonitis represent systemic infection and occur in <1% of patients treated with BCG.[31] Granulomatous hepatitis presents with typical signs and symptoms of hepatitis, such as fever, jaundice, and anorexia. Granulomatous pneumonitis presents with general malaise, shortness of breath, and fever >101°F. One death has been reported from granulomatous hepatitis and BCG sepsis.[42] A full fever workup that includes elevated liver enzymes and a chest radiograph or CT scan are needed to delineate the diagnosis. Liver biopsy is required to confirm the presence of granulomatous hepatitis. Hospitalization, fluid resuscitation, and acetaminophen are essential. INH and rifampin are given for 3 months with ethambutol added for severely ill patients. The incidence of hypersensitivity reaction from BCG is unclear, but investigators have reported that some granulomatous reactions result from an immune rather than an infectious process.[30,43,44] Although no controlled studies have been conducted of steroid therapy in BCG-infected patients, preliminary data reveal that prednisolone (40 mg/day) may be added in unremitting conditions, as in the case of BCG sepsis.[45–47]

Granulomatous reactions also occur in the bladder.[47,48] Contracted bladder occurs in <1% of patients, but patients receiving maintenance therapy may be at higher risk, and some investigators have advocated use of prophylactic INH to decrease the likelihood of this complication. Management of contracted bladder consists of hydrodistention and withholding of BCG.[32] If conservative measures fail, cystectomy may be required.[49] Ureteral obstruction may occur secondary to edema or inflammation of the orifice and is reported in <0.3% of patients. CIS and vesicoureteral reflux are probably predisposing factors.[50] This rare complication may require ureteral stenting or percutaneous drainage to relieve the obstruction.[32]

Granulomatous reactions of the bone and bone marrow may rarely occur. Osteomyelitis of the vertebral bodies has been reported. Patients can present with back pain or even motor weakness.[51] The presence of cytopenia should arouse suspicion of bone marrow involvement. Treatment is with antituberculosis therapy and cessation of BCG therapy.[52]

Arthralgic Complications

Arthralgia and arthritis are some of the rare severe complications associated with BCG therapy. Joint involvement occurs in approximately 0.5% of cases.[31] Arthritis usually occurs ≤2 weeks after the last instillation, whereas arthralgias can appear within a few days of instillation and become more severe with further instillations.[53] Arthritis may occur within the complex of Reiter syndrome.[54] The symptoms may resolve with NSAID treatment. If symptoms persist, administration of antituberculosis drugs and steroids should be considered.[40]

Arthralgias with associated skin rash likely indicate an allergic reaction to BCG. Treatment begins with NSAIDs and antihistamines. Refractory or severe symptoms require discontinuation of BCG and use of INH, rifampin, quinolones, and steroids.[32]

Rare Complications

Penile edema and meatal ulceration have been reported with and without lymph node enlargement.[55] A 3-month course of INH and rifampin therapy should be given. Cutaneous complications of BCG therapy are rare, but penile edema and meatal ulceration suggest the possibility of local spillage.[56] Other rare reported complications include nephrogenic adenoma, immune complex glomerulonephritis, choroiditis, cardiac toxicity, suppurative lymphadenitis, mycotic aneurysm, aortoduodenal fistula, lupus vulgaris, and musculoskeletal lesions.

CONTINUING THERAPY AND MAINTENANCE

Patients experiencing mild local and systemic inflammatory side effects can be safely continued on an unmodified dose of BCG. In individuals experiencing severe local side effects or systemic toxicity lasting >48 hours, we recommend withholding the dose until symptoms have resolved and then resuming treatment with a lower dose of BCG (1/3, 1/6, 1/12, or 1/100 dilution) to reduce the severity of symptoms.[32,57] Evidence suggests that 1/3 dilutions are the minimum effective dose in maintenance.[18,20] In our practice, however, we have occasionally reduced the dose to 1/6 or 1/12, transiently, with later a attempt to increase the dose back to a 1/3 dose. In general, prophylactic use of INH is not indicated unless the clinician suspects systemic absorption of the organism. Prophylactic ofloxacin 200 mg given twice following each BCG instillation is a reasonable option to reduce side effects.[29] We have always been concerned that quinolones have the potential to reduce efficacy given their cytotoxic effect on the BCG organism.

In patients with high fever or severe local symptoms, once the symptoms resolve, the clinician should rule out obvious reasons for systemic absorption such as traumatic catheterization, bladder wall ulceration, or timing in relation to transurethral resection. Individuals who have experienced severe systemic illness or sepsis should not receive further BCG therapy.

Numerous studies have shown that long-term maintenance therapy is associated with a poor rate of compliance, ranging from 16% to 65.5%.[58–61] In comparison with nonmaintenance regimens, patients undergoing maintenance therapy clearly have a greater incidence of side effects, and compliance seems directly related to the duration and total number of instillations.[59] Most treatment cessations are secondary to local or regional symptoms of irritation. Although low-grade fever is common and increases in incidence with successive maintenance doses, this complication has not been found to be associated with cessation of therapy.[62] Recent evidence suggests that in patients without high-risk cancer, 1 year of maintenance therapy is effective and thus might be an option in patients with intolerable side effects.[21] Alternatively, we have used a modified regimen of administration at 3, 6, 12, 18, 24, 36, 48, and 72 months. Anecdotally, this regimen has been better tolerated.

In follow-up, we have generally chosen to perform cystoscopy no sooner than 3 months following BCG administration, in part because of the high likelihood of ongoing bladder wall inflammation, but additionally because of the need for an adequate period to allow therapeutic efficacy, particularly in the setting of CIS. BCG inflammation can take on several appearances, but typically is demonstrated as a patch of raised, friable erythema, or bullous edema, in the dome of the bladder. Similar findings, located at the previous site of resection, are commonly observed as well. Use of cytology, and biopsy if cytology is abnormal, can differentiate apparent BCG inflammation from persistent urothelial cancer. In cases of normal cytology, deferral of maintenance BCG for 6 weeks with repeat inspection can be considered prior to biopsy.

PURIFIED PROTEIN DERIVATIVE CONVERSION

Routine purified protein derivative (PPD) skin testing prior to administering intravesical BCG is unnecessary, as most patients in the United States are at low risk for active tuberculosis infection.[63] A positive PPD test without evidence of active disease is not a contraindication to intravesical BCG. PPD positivity may in fact be encouraging, as patients with prior immunity to BCG as demonstrated by a positive PPD may have improved recurrence-free survival without experiencing greater toxicity.[64,65]

PPD conversion to a positive test result occurs in approximately 34% of patients previously treated with intravesical BCG and should not be considered a complication of

BCG therapy.[66] Although favorable responses to treatment have been shown to occur more frequently in patients with PPD conversion, this factor has not been shown to be a reliable indicator of either prognosis or tolerance of therapy.[31,67]

CONTRAINDICATIONS

Classic contraindications to BCG therapy include human immunodeficiency virus (HIV) infection, leukemia, lymphoma, organ transplantation, pregnancy, breast-feeding, active tuberculosis, and intractable UTIs.[68] In severely immunocompromised patients, there is a theoretical concern for increased risk of systemic BCG toxicity. However, limited evidence has demonstrated efficacy and safety in some of these patient groups.

Yossepowitch and colleagues evaluated the use of BCG induction therapy in 24 "immunocompromised patients" with lymphoma, chronic obstructive pulmonary disease, or steroid therapy and found a response rate of 58% overall; only a single patient experienced a self-limited febrile illness (≤39.3°C for 48 hours after his third BCG cycle).[69]

BCG therapy has been safely given in several small studies of patients with renal transplants.[70–73] Some investigators utilized prophylactic antituberculosis drugs and adjusted immunosuppressive doses due to possible drug interactions.[70,71] Herr and colleagues administered an induction course of BCG in 45 immunosuppressed patients, including those with organ transplants, cancer treated with chemotherapy, or corticosteroid use.[73] Transplant patients experienced higher rates of treatment failure, recurrence, and progression. No patients in this cohort developed bacterial or BCG sepsis. Thus, they concluded that intravesical BCG is effective and safe in these immunocompromised patients. Caution should still be practiced when considering intravesical BCG in immunocompromised patients, as there is only preliminary evidence suggesting its safety. Severely immunocompromised patients should not undergo BCG therapy.

There are scarce data regarding the use of intravesical BCG in patients with HIV.[72] Only two such patients were identified, one of whom with a CD4+ lymphocyte count of 10/mm^3 developed interstitial pneumonitis following BCG therapy.[74,75] In patients with HIV well-controlled with medications, BCG therapy might be safe but is yet unproven.[63]

No contraindication exists for BCG therapy in patients with valvular heart disease, prosthetic heart valves, or orthopedic hardware. Appropriate antibiotic prophylaxis for bacterial endocarditis should be administered in these patients before urethral instrumentation is undertaken but is not necessary for simple urethral catheterization during BCG instillation.[63]

Another area of debate is transmission of BCG by sexual intercourse. Even though no cases of sexual transmission have been reported, use of a condom is generally advised during sexual intercourse for 1 week after BCG therapy.

BCG may be given to patients with vesicoureteral reflux without significant risk of complication.[76] Some investigators have advocated resection of the ureteral orifices to induce reflux before BCG therapy to increase the proportion of urothelium in contact with BCG. Only one case of necrotic pyelonephritis has been reported. When patients do develop severe febrile reactions to BCG, consideration should be given to BCG pyelonephritis or renal abscess.

INTERFERONS

Interferons (IFNs) are proteins with antiviral, antiproliferative, and immunomodulatory properties. Three classes of IFNs are recognized:[77] IFN-α, IFN-β, and IFN-γ derive from leukocytes, fibroblasts, and lymphocytes, respectively. IFNs stimulate macrophages for antigen presentation, promote cytokine release, enhance natural killer cell activity, and indirectly activate T and B lymphocytes.[78]

The best studied IFN is IFN-α. When it is used alone, this agent is well tolerated, with minimal local inflammatory effects or low-grade fever.[79] Efficacy depends on dose (range, 10 million to 100 million U). IFN-α is less effective and more expensive than BCG, and therefore its primary use is in salvage intravesical therapy for BCG-refractory tumors.[58,80,81] In patients with CIS and BCG treatment failure, the complete response to IFN-α is 15–20% at 1 year, with a durable response rate of 12% by 2 to 3 years.[26]

COMPLICATIONS

Most side effects of IFN are the result of the systemic inflammatory response generated by lymphokine release. Acute IFN toxicity consists of flulike symptoms, which occur in 0–27% of patients and include chills, fever, headache, malaise, and myalgia.[79,82] Chronic toxicities include fatigue, weight loss, and anemia. Some patients (0–10%) develop local cystitis and hematuria.[17] Most adverse events resolve with expectant management within 24 to 48 hours of onset or on discontinuation of therapy. Acetaminophen can be used as a supportive agent to reduce fever and myalgia. Although treatment is generally symptomatic, dose reduction can aid in the completion of therapy.

O'Donnell and colleagues conducted a phase II randomized trial comparing IFN alfa-2b with BCG and found systemic side effects in 5.3% of patients.[80] The use of low-dose BCG showed a trend toward decreased severe inflammatory and infectious events.

Although most toxicities associated with intravesical IFN are mild, transient, and completely reversible on discontinuation of therapy, these symptoms can occasionally interfere with patient compliance and completion of therapy. Dose reduction (25 or 10 million U, if necessary) offers a potential means of continuing therapy.

INTRAVESICAL CHEMOTHERAPY

Intravesical chemotherapy is an important class of therapeutics for treatment of Ta and T1 bladder carcinoma. The most commonly used drugs are mitomycin C (MMC), epirubicin, doxorubicin, valrubicin, and gemcitabine. Intravesical chemotherapy can usually be administered immediately following transurethral resection. Given the high molecular weight of chemotherapeutic drugs, the risk of absorption is low; consequently, systemic toxicity is of smaller concern than with BCG. Local symptoms due to irritation are most prevalent, and few side effects are immunologically mediated. As such, the side effects of individual agents are

commonly related to the drug itself. Furthermore, the use of intravesical chemotherapy precludes the risk of sepsis and death associated with BCG therapy.

MITOMYCIN C

Mitomycin C is an antibiotic chemotherapeutic alkylating agent that acts by inhibiting DNA synthesis.[83,84] Because of its high molecular weight, MMC is not easily absorbed and has a lower incidence of systemic reactions. This agent has been used in 20- to 60-mg doses for 8 weeks, although the usual dose is 40 mg in 40 mL of saline or water intravesically for 8 weeks followed by monthly maintenance therapy for 1 year in most studies. Table 22.2 summarizes the different schedules of intravesical MMC therapy and their associated side effects.

Chemical cystitis, the most common side effect of MMC therapy, has an incidence of 3–33%.[85,86] Genitourinary toxicity occurs even with a single dose of perioperative MMC, with one study reporting symptoms in 28% of 116 patients receiving MMC following tumor resection.[87] Symptoms generally respond to phenazopyridine and anticholinergics, but ≤3% of patients may require discontinuation of therapy because of severe cystitis.[67] Common symptoms include dysuria, suprapubic discomfort, and urinary frequency and urgency. UTI should be ruled out before palliative therapy is instituted; before discontinuation of therapy, consideration should be given to reducing the dose. Toxicity partly depends on the dose administered, but cystitis can occur even at low doses.

The incidence of dermatologic toxicity with MMC ranges from 4% to 12% in most series. Contact dermatitis may result from a delayed hypersensitivity reaction or direct contact of the drug with the skin.[88] Delayed hypersensitivity as a cause was postulated after deGroote and colleagues reported on six patients, all of whom developed rash after their second instillation, a finding suggesting that MMC sensitization was required for the dermatitis to occur. Contact dermatitis can manifest as an eczema-like desquamation of the skin of the palms, soles of the feet, perineum, chest, and face. Other investigators have reported a generalized rash.[67,89] There is a report of penile gangrene secondary to MMC contact dermatitis that ultimately required penectomy.[56] Contact dermatitis due to allergic reaction may rarely present with associated eosinophilic cystitis, causing severe voiding symptoms that usually necessitate cessation of MMC therapy.[90]

Dermatologic toxicity may be prevented by careful cleansing of the hands and genitals after voiding. When a rash does arise, MMC therapy is generally discontinued, though topical steroids can sometimes suppress the reaction sufficiently to continue therapy.[88] In most cases, repeat treatment results in recurrence of the dermatitis. Some investigators have suggested skin testing patients with a 0.1% MMC petroleum patch to observe whether a systemic response occurs, but this approach has not gained favor.[91]

Myelosuppression after intravesical MMC therapy is rare but has been reported by multiple investigators.[92] In general, patients appear to have coexisting risk factors for leukopenia, thus making it difficult to assess the causative

Table 22.2 Toxicity of Intravesically Administered Mitomycin C

Study (year)	No. Patients	Induction Dose	Dose Frequency	Chemical Cystitis	Bladder Capacity Reduction	Contact Dermatitis	Leukopenia	Thrombocytopenia
Nissenkorn et al (1981)[89]	29	8 × 40 mg/mL	Weekly induction; every	3 (10%)	None	3 (10%)	None	None
Prout et al (1982)[83]	28	8 × 40 mg/mL	Weekly induction	9 (32%)	None	None	None	None
Issell et al (1984)[122]	60	8 × 40 mg/mL	Weekly induction	33%	None	7 (12%)	3 (5%)	1 (2%)
Huland et al (1990)[85]	209	20 mg/20 mL	Every 4 wk × 1 yr; every 3 mo × 1 yr	25%	None	None	None	None
	96	20 mg/20 mL	Weekly × 8 wk; Monthly × 3 yr	12%	None	None	None	None
	75	20 mg/20 mL	Weekly × 20 wk	18%	None	None	None	None
Eijsten et al (1990)[86]	75	2 × 20 mg or 30 mg; 2 doses in first wk	Every 2 wk × 6 mo; Monthly × 6 mo; every 2 mo × 1 yr	None	17 (23%)	None	None	None
Rintala et al (1996)[67]	93	5 × 20–40 mg	Weekly induction; every mo × 1 yr; every 3 mo × 1 yr	3 (3%)	None	3 (3%)	None	None
Bohle et al (2003)[16]	776	Meta-analysis	Meta-analysis	39.2%	NA	NA	NA	NA
Friedrich et al (2007)[117]	179	20 mg	Weekly × 6 wk	11.6%	None	None	None	None
	153	20 mg	Weekly × 6 wk; monthly × 3 yr	20.5%	None	None	None	None
Filson et al (2014)[87]	116	40 mg/40 mL	Single perioperative dose	27.6%	None	None	None	None

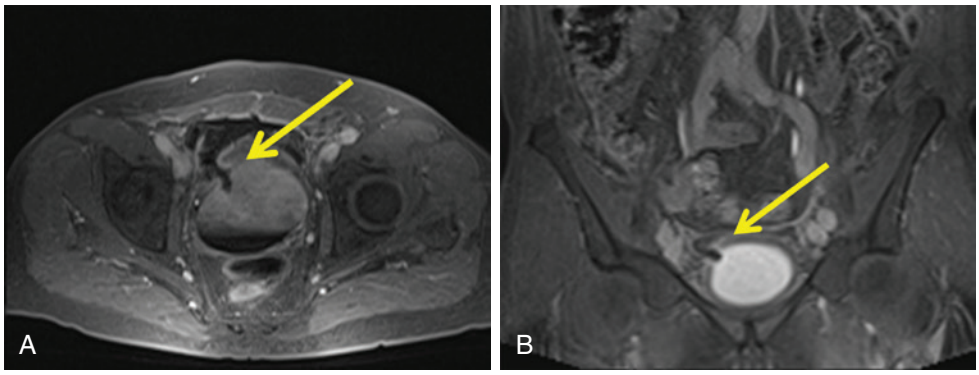


Figure 22.1 Magnetic resonance imaging urogram of a patient with severe pelvic pain following perioperative mitomycin instillation. A, On axial imaging a perivesical phlegmon with fat necrosis extending to an apparent breach in the bladder well is noted (see arrow). B, On urographic phase, coronal section unrecognized extravesical bladder perforation is noted with fat necrosis extending into the bladder lumen with layering of lipid in the bladder (see arrow).

factor. Myelosuppression is rare enough that routine monitoring is not necessary. If myelosuppression occurs, intravesical MMC should be stopped and white blood cell count should be monitored.

A relatively infrequent complication of MMC instillation is bladder contracture.[86] Although a reduction in bladder capacity has been reported by numerous investigators, interpretation of the finding is difficult because in most cases, pretreatment bladder capacity is not measured. In patients with a severe reduction in bladder capacity, it appears that MMC administration at the time of resection is the major risk factor, and the most likely contributor is extravasation. Selecting patients carefully based on the extent and depth of resection, and particularly avoiding administration in the setting of perforation, may decrease the risk.

Contraindications to MMC instillation include suspected bladder perforation during tumor resection, pregnancy, and previous allergic reaction or severe adverse reaction to MMC. MMC may cause peritonitis, abdominal or pelvic pain, fibrosis, and necrosis if bladder perforation and extravasation occur.[93–95] Affected patients may suffer from chronic pelvic pain or require surgical reconstruction.[96] Urologists must constantly be aware of the depth of transurethral resection, and if perforation is suspected, MMC should be withheld until a cystogram is done to confirm bladder integrity. In rare instances, extravasation may be a direct effect of MMC-induced transmural muscle necrosis.[94] Allergic reactions generally manifest as the aforementioned skin rashes or, rarely, as eosinophilic cystitis.[90]

In patients with severe cystitis symptoms with or without pelvic pain, cross-sectional imaging is indicated to rule out extravesical or bladder wall necrosis, bladder fistula, or pelvic abscess (Fig. 22.1). Cystoscopy typically demonstrates severe inflammation, with bullous edema, surface necrosis of the urothelium, and punctate hemorrhage surrounding sites of resection (Fig. 22.2), often as a concentric ring at the dome of the bladder. In cases of bladder wall fistula to the surrounding perivesical fat, the actual fistula may not be seen, but droplets of fat are often observed floating in the bladder. In these cases, simple observation with administration of pain medication, urinary analgesics, and, when needed, antimuscarinic agents is a reasonable first course. Healing can take several months in cases of bladder fistula,



Figure 22.2 Cystoscopic view of severe mitomycin reaction in a patient administered perioperative mitomycin following resection of a papillary bladder tumor. Local reaction with bullous, hemorrhagic edema surround the resection bed.

but severe cystitis will generally resolve within 3 months. Transurethral resection of necrotic tissue can be considered in cases of secondary infection or when large amounts of necrotic debris are noted in the bladder, but caution must be exerted to avoid overt perforation. Additional intravesical therapy, particularly BCG, should be withheld until complete resolution of cystitis and healing of the bladder in cases of fistula. Upon healing, a stellate scar will be visible at the site of the previous fistula and, depending upon the amount of bladder wall necrosis and perivesical fibrosis, bladder function or compliance can be affected. Secondary bladder augmentation is rarely required, and generally should be avoided until a prolonged cancer-free interval is noted. Visual inspection of the bladder previously treated with mitomycin will often demonstrate multifocal telangiectasias as a result of bladder wall healing (Fig. 22.3).

THIOTEPA

Thiotepa was used in the past for nonmuscle invasive bladder cancer at high-risk for recurrence due to tumor multifocality, frequent recurrence, or high-grade disease associated with urothelial atypical cancer or CIS. The drug was appealing because of its low cost, but it lost appeal because of the availability of anthracycline compounds and of the relatively higher risk of systemic absorption and myelosuppression. Unlike MMC, thiotepa has a low molecular weight, which allows as much as one-third of the drug to be absorbed through the urothelium when it is retained in the bladder for 3 hours.[84] Because of the low molecular weight, the high rate of absorption, and the potential for bone marrow suppression associated with thiotepa, the treating physician should be extremely cautious when administering this agent (Table 22.3).

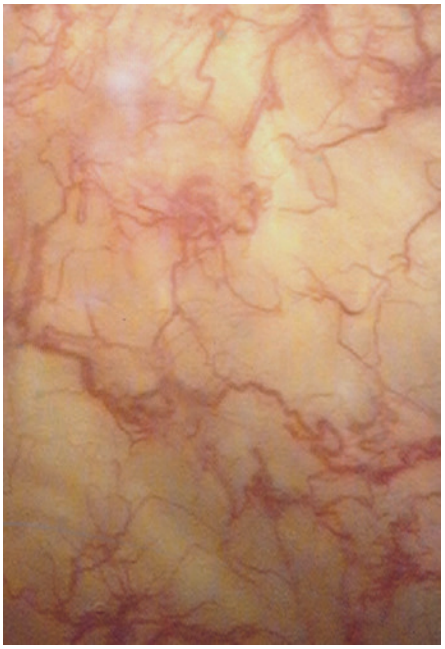


Figure 22.3 Cystoscopic appearance of the urothelium in a patient previously administered mitomycin for nonmuscle invasive bladder cancer. The urothelium is well healed with a hypervascular pattern consisting of multiple telangiectasias.

DOXORUBICIN, EPIRUBICIN, AND VALRUBICIN

Doxorubicin, epirubicin, and valrubicin are anthracycline antibiotics. Doxorubicin is used primarily for pTa and pT1 tumors for treatment and prophylaxis. BCG is superior for the treatment of CIS, but doxorubicin may be used in patients who cannot tolerate BCG. Because of its large molecular weight, doxorubicin is minimally absorbed and has few systemic complications. Local toxicity, however, is far more common (Table 22.4).

Chemical cystitis manifesting as dysuria, frequency, urgency, and suprapubic pain is seen in 13–56% of patients.[84] Management involves symptomatic care and urine cultures to rule out bacterial infection. Local treatment with phenazopyridine or anticholinergics provides relief of mild symptoms.

Systemic side effects are uncommon and occur in <5% of patients in most series. Rare systemic side effects include gastrointestinal upset, fever, and rare hypersensitivity reactions. In very rare reported instances, hypersensitivity reactions manifested with tachypnea and bronchospasm and were treated with diphenhydramine; in one case, subcutaneous epinephrine was required.[97,98]

Epirubicin is similar to doxorubicin but has become more popular, especially in Europe, because of comparable or improved efficacy and decreased toxicity relative to doxorubicin. Numerous investigators have verified the efficacy of epirubicin in the treatment of superficial bladder cancer.[99–104] Theo and colleagues randomized 168 patients to either 50 mg epirubicin or 81 mg BCG for CIS.[99] The clinical response rate was equivalent for the two agents; however, time to tumor recurrence after initial clinical response was longer in patients treated with BCG than in those treated with epirubicin (5.1 vs 1.4 years). A higher rate of CIS recurrence was noted with epirubicin than with BCG therapy (45% vs 16%).[99] In the epirubicin-treated

Table 22.3 Toxicity of Intravesically Administered Thiotepa

Study (year)	No. Patients	Induction Dose	Dose Frequency	Leukopenia	Thrombocytopenia	Deaths	Irritative Voiding Symptoms
Abbassian and Wallace (1996)[123]	13	4 × 90 mg/50 mL	Every 4 days	7 (54%)	None	2	9 (69%)
Gavrell et al (1978)[124]	22	6 × 30 mg/60 mL, *or* 30 mg/60 mL	2/day every mo × 1 yr	2 (9%)	None	None	3 (14%)
Hollister and Coleman (1980)[125]	29	60 mg/30 mL	Weekly, biweekly, or monthly × 1 yr	5 (17%)	9 (31%)	2	
Heney et al (1988)[76]	73	8 × 30 mg/30 mL	Every wk	15 (21%)		None	22 (30%)
Martinez-Pineiro et al (1990)[119]	56	4 × 50 mg/mL	Every mo × 11 mo	None	None	None	8 (14%)
Bouffioux et al (1992)[126]	103	4 × 50 mg/mL	Every week; every mo × 1 yr	None	1 (1%)	None	2 (2%)

Table 22.4 Toxicity of Intravesically Administered Doxorubicin

Study (year)	No. Patients	Dose Induction	Dose Frequency	Chemical Cystitis	Systemic Toxicity
Schulman et al (1984)[127]	110	6 × 50 mg/50 mL	2 × 1st wk; every mo × 1 yr; every 3 mo × 1 yr	29 (26%)	None
Garnick et al (1984)[128]	27	8 × 60–90 mg/40–50 mL	Every 3 wk; every 6 wk × 2; every 12 wk × 2	15 (56%)	None
Huland et al (1990)[85]	39	50 mg/mL	Every 2 wk × 1 yr; every mo × 1 yr; every 3 mo × 1 yr	48%	Unknown
Martinez-Pineiro et al (1990)[119]	53	50 mg/50 mL weekly × 4 wk	Every mo × 1 yr	13%	None
Ali-el-Dein et al (1997)[98]	60	50 mg/50 mL weekly × 8 wk	Every mo × 1 yr	22 (37%)	3 (5%)
Okamura et al (2002)[129]	84	30 mg/30 mL	Single perioperative dose	10.7%	None

Table 22.5 Toxicity of Intravesically Administered Gemcitabine

Study (year)	No. Patients	Dose	Dose Frequency	Local Toxicity	Systemic Toxicity
Bartoletti et al (2005)[108]	114	2000 mg/50 mL	Weekly × 6 wk	12%	5% (fever)
Dalbagni et al (2006)[111]	30	2000 mg/100 mL	Twice weekly × 6 wk	33%	3% (infection) 7% (rash)
Di Lorenzo et al (2010)[114]	40	2000 mg/50 mL	Twice weekly × 6 wk; weekly × 3 at 3, 6, 12 mo	15%	3% (fever) 5% (neutropenia, thrombocytopenia) 5% (rash)
Addeo et al (2010)[115]	109	2000 mg/50 mL	Weekly × 6 wk; monthly × 1 yr	9.2%	6% (rash)
Skinner et al (2013)[112]	55	2000 mg/100 mL	Weekly × 6 wk; monthly × 1 yr	62%	2% (neutropenia)
Sternberg et al (2013)[113]	69	2000 mg/100 mL	Twice weekly × 6 wk	40%	10% (rash) 3% (fever) 3% (infection) 1% (thrombocytopenia)

group, systemic toxicity was very rare and mild, ranging from skin rash to general malaise. Both local and systemic side effects were more commonly observed in the BCG-treated group. Due to these side effects, 26 patients stopped treatment in the BCG group, as opposed to only eight patients in the epirubicin group.

Valrubicin is a semisynthetic analog of doxorubicin. It has demonstrated antitumor activity in the treatment of superficial bladder cancer and superior efficacy with lower risk of contact and cardiac toxicity compared to doxorubicin in animal models.[105] Valrubicin has gained FDA approval for its role in BCG-refractory CIS in patients who are not candidates for cystectomy. Local bladder symptoms due to valrubicin are mild and rarely cause early cessation of therapy. Symptoms such as urinary frequency, urgency, and dysuria occurred in approximately 50–60% of patients in the two largest studies.[106,107] Other less common side effects include UTI, asthenia, urinary retention, and foul-smelling urine with or without passing of tissue.

GEMCITABINE

Gemcitabine is a pyrimidine analog that inhibits DNA synthesis through insertion into the DNA sequence and inhibition of ribonucleotide reductase, which prevent downstream DNA polymerization and nucleotide synthesis, respectively.[108] In patients with advanced or metastatic bladder cancer, systemic administration of gemcitabine has proven efficacious and to be well-tolerated.[109,110] Several studies have demonstrated that an induction course of intravesical gemcitabine is effective in treatment-naïve and BCG-refractory disease.[108,111–113]

BCG-refractory disease treated with gemcitabine has a relatively high rate of recurrence at 1 year of follow-up, even with 1 year of maintenance therapy.[111,112] However, this represents a group that is difficult to treat and would otherwise be relegated to cystectomy. In a randomized study of 80 patients who previously failed one course of BCG, patients treated with gemcitabine had a reduced rate of recurrence relative to those treated with BCG, after 1 year of maintenance therapy of each drug.[114] Another randomized study of 120 patients with BCG-refractory disease demonstrated that gemcitabine was more efficacious and less locally toxic than MMC.[115]

Intravesical gemcitabine is extremely well-tolerated, allowing high rates of completion with therapy. Side effects are summarized in Table 22.5. Local urinary symptoms occur in 10–40% of patients and are generally mild. One

study evaluating a maintenance regimen of gemcitabine found mild local toxicity in 62% of patients; however, there was no increase in toxicity with higher numbers of instillations.[112] Although there are no studies evaluating their efficacy in this setting, anticholinergics and phenazopyridine can be utilized to alleviate local symptoms. Systemic toxicity is rare but can include infection, dermatitis, fever, neutropenia, and thrombocytopenia.

Conclusions

The management of nonmuscle invasive bladder cancer is greatly aided by the use of intravesically administered adjuvant therapies. The use of these therapies is generally safe, and with precautions, such as careful techniques of administration, patient selection, and patient observation, long-term sequelae should be minimal. Thorough knowledge of the individual toxicity profile of each agent is essential for the practicing urologist. Although various agents carry different risks of toxicity, adherence to the standard treatment principles of intravesical therapy, outlined in this chapter, will minimize the likelihood of complications.

References

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Chapter 22 Questions

1. Which dilution of the standard bacille Calmette-Guérin (BCG) dose reduces toxicity without compromising efficacy?
   a. 1/2 dilution
   b. 1/3 dilution
   c. 1/6 dilution
   d. 1/12 dilution
   e. 1/100 dilution

2. Which drug can be used prophylactically to reduce adverse effects of intravesical BCG?
   a. Corticosteroids
   b. Isoniazid (INH)
   c. Ofloxacin
   d. Rifampin
   e. Nonsteroidal antiinflammatory drugs (NSAIDs)

3. What is the most common adverse effect of BCG therapy?
   a. Fever
   b. Irritative voiding symptoms
   c. Skin rash
   d. Pneumonia
   e. Sepsis

4. Which of the following is an appropriate first-line treatment for BCG sepsis?
   a. INH, rifampin, ethambutol, prednisone, cycloserine
   b. INH, rifampin, prednisone
   c. Rifampin, pyrazinamide, prednisone
   d. INH, rifampin, ethambutol, prednisone, ciprofloxacin
   e. INH alone

5. Perioperative intravesical mitomycin C (MMC) is planned for a patient following transurethral resection of bladder tumor. After an extensive resection, bladder perforation is suspected. Which of the following is the most appropriate next step?
   a. Withhold mitomycin until a cystogram can be performed
   b. Proceed with intravesical MMC
   c. Proceed with intravesical gemcitabine
   d. Proceed with a lower dose of intravesical MMC
   e. Leave the catheter for 24 hours and then administer MMC

6. Which of the following is *not* a contraindication to intravesical BCG?
   a. Hematuria
   b. HIV/AIDS
   c. Positive purified protein derivative (PPD) skin test
   d. Traumatic catheterization
   e. Transurethral resection within 1 week

7. Which adverse effect of intravesical MMC can be immune-mediated?
   a. Cystitis
   b. Myelosuppression
   c. Bladder contracture
   d. Skin rash
   e. Fistula

8. For which indication does valrubicin have FDA approval?
   a. BCG-refractory carcinoma in situ (CIS)
   b. BCG-refractory papillary tumors
   c. Muscle invasive bladder cancer
   d. Treatment-naïve CIS
   e. Upper tract CIS

9. A 70-year-old man undergoing BCG maintenance therapy presents with fever and left testicular pain. Which of the following is the most likely diagnosis?
   a. Granulomatous epididymo-orchitis
   b. Testicular torsion
   c. Bacterial epididymo-orchitis
   d. Granulomatous prostatitis
   e. Testicular tumor

10. After undergoing an instillation of BCG, a patient experiences a fever of 101.1°F for 8 hours. What is the best next step in management?
    a. INH, rifampin, ethambutol, prednisone
    b. Acetaminophen
    c. Ofloxacin
    d. Withhold further BCG therapy
    e. Admission to hospital

Case Study 1

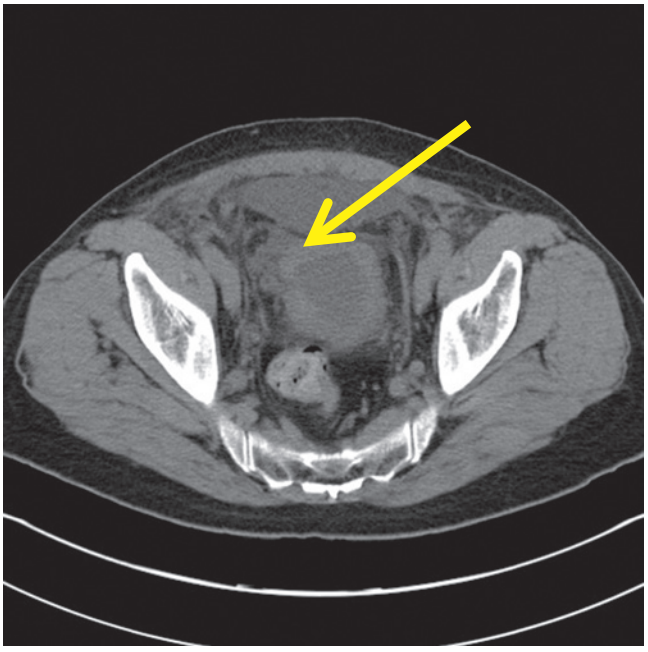
1. A 63-year-old man with a 3-cm papillary bladder tumor undergoes a transurethral resection of the tumor with plan for perioperative administration of intravesical mitomycin (Case Fig. 22.1). There is visible thinning of the bladder wall, with no evidence of perforation. The next step is:
   a. Proceed with planned mitomycin administration
   b. Proceed with reduced-dose mitomycin administration
   c. Delay mitomycin administration for 24 hours
   d. Withhold mitomycin
   e. Cystogram prior to mitomycin administration

2. Following administration of mitomycin, the patient develops severe dysuria within 72 hours. He notes right lower quadrant abdominal pain, urinary frequency, and urgency. He denies fever or chills. CT scan is shown (Case Fig. 22.2). The next step is:
   a. Pain medication, urinary analgesic, and antimuscarinics
   b. Intravenous antibiotics, bowel rest
   c. Cystoscopy, bladder debridement
   d. Catheter drainage
   e. Exploration and bladder repair

3. Nine months following resection, the patient's symptoms have largely dissipated. He reports mild urinary frequency without dysuria or pain. He is noted to have multifocal papillary recurrence. At time of resection, no perforation is noted. Pathology demonstrates



Case Figure 22.1



Case Figure 22.2

high-grade pTa urothelial cancer with focal CIS. The next step is:
a. Continued surveillance
b. Intravesical mitomycin administration
c. Cystogram followed by mitomycin administration
d. BCG induction therapy
e. Cystectomy

Case Study 2

1. A 60-year-old woman is administered induction BCG following the diagnosis of high-grade nonmuscle invasive bladder cancer. Following administration of the fourth dose, she experiences fever of 100.8°F, severe muscle aches, and fatigue persisting for 18 hours. The next step is:
   a. Antipyretics, analgesics, supportive care
   b. Quinolone antibiotics
   c. Discontinue BCG
   d. Intravenous antibiotics
   e. Intravenous antibiotics and antituberculous agents

2. Given a favorable response to BCG, a maintenance regimen is initiated. After the second dose of the third maintenance cycle, the patient develops severe, persistent dysuria and pelvic pain. Urine culture and cytology are negative. Cystoscopy is consistent with severe BCG inflammation, and biopsy shows no cancer. After 4 weeks of supportive care, symptoms persist without great improvement. The next step is:
   a. Analgesics and antimuscarinics
   b. Cystoscopy and resection of ulcerations
   c. Intravenous antibiotics
   d. Antituberculous agents
   e. Cross-sectional imaging

3. After a course of antituberculous agents for 3 months, the patient's symptoms largely resolve. She is noted to have persistent urinary frequency without pain. Evaluation reveals a reduced bladder capacity of 120 mL, with poor bladder compliance. Urine culture, cytology, and cystoscopy are normal. The next step is:
   a. Bladder biopsy
   b. Full-dose maintenance BCG
   c. 1/3-dose maintenance BCG
   d. Full-dose maintenance BCG with catheter in place
   e. Cessation of BCG therapy

Answers

1. **b.** Three studies from the CUETO group evaluated varying doses of BCG. Initially, it was demonstrated that 27 mg BCG (1/3 dilution) provides an equivalent reduction in disease recurrence and progression and less toxicity compared to 81 mg BCG. A subsequent study found that 13.5 mg (1/6 dilution) was inferior to 27 mg BCG. Another study from the EORTC-GU group confirmed that 1/3-dose has comparable efficacy to full-dose BCG.
2. **c.** Ofloxacin 200 mg given twice after each BCG instillation was found to reduce toxicity and improve compliance with BCG therapy. Antituberculosis therapy (e.g., INH, rifampin) has not demonstrated efficacy in the prophylactic setting. Corticosteroids are an important component of treatment for systemic BCG toxicity (e.g., BCG sepsis). NSAIDs are often used to treat systemic inflammatory toxicity of mild severity.
3. **b.** Irritative voiding symptoms, similar to those of cystitis, occur in 27–90% of patients treated with BCG. These symptoms usually arise after the third instillation and are the most common reason for early cessation of treatment. Treatment is with phenazopyridine or anticholinergics. If severe, consider dose reduction, prophylactic quinolones, or cessation of BCG therapy.
4. **d.** BCG sepsis should be managed with cessation of BCG therapy and administration of INH, rifampin,

ethambutol, corticosteroids, and quinolones. Addition of gram-negative coverage and another antituberculosis agent can be considered. Cycloserine and pyrazinamide are ineffective against some BCG strains and are thus not appropriate. BCG sepsis may be caused in part by a delayed-type hypersensitivity reaction, which explains the role for prednisone in its management.

5. **a.** Due to its high molecular weight, MMC is generally not absorbed systemically. In the setting of bladder perforation, however, MMC may cause peritonitis, pelvic pain, fibrosis, and necrosis. If MMC is absorbed into the extravesical space, bladder contracture and chronic pain may result. If there is concern for bladder perforation, MMC should be withheld until bladder integrity can be confirmed. Similarly, in cases of extensive resection, a post-instillation inflammatory response can be quite severe and prolonged. In these cases, caution should be exercised, and if there is any concern, the dose withheld to avoid prolonged toxicity.
6. **c.** Patients with a positive PPD can safely undergo BCG therapy as long as there is no active infection with tuberculosis. In fact, intravesical BCG may be more effective in patients with prior PPD positivity. Severely immunocompromised patients, including those with HIV/AIDS, should not receive BCG. However, there is some evidence suggesting BCG is safe in patients with renal transplant, corticosteroid use, leukemia, or lymphoma. After transurethral resection, 2 weeks should pass before administering BCG. Traumatic catheterization warrants waiting 1 week before giving BCG. Hematuria should resolve before BCG is administered.
7. **d.** MMC is believed to cause skin rashes through two mechanisms: direct contact or delayed hypersensitivity. Thus, steroids can be used in the treatment of MMC-induced rash, though further treatment often must be discontinued due to recurrence of the rash. The remaining side effects of MMC are due to the direct toxicity of the drug.
8. **a.** Valrubicin is FDA-approved to treat BCG-refractory CIS and is especially important in patients who are not candidates for cystectomy. Gemcitabine has also demonstrated efficacy in this patient group.
9. **c.** Granulomatous epididymo-orchitis is a rare complication of BCG therapy. Typical presentation is local induration and pain in the testis with possible fever or leukocytosis. Bacterial infection should be excluded with urine culture, as this is a more common cause of epididymo-orchitis even in the setting of BCG therapy. Granulomatous epididymo-orchitis should be treated with INH, rifampin, steroids, and fluoroquinolones.
10. **b.** Low-grade fever (<101.3°F) is common during BCG therapy. It typically lasts 24 to 48 hours and can be treated with acetaminophen or NSAIDs. If the fever persists for greater than 48 hours or increases in severity (>102°F), BCG sepsis may have developed and antituberculosis therapy is warranted.

CASE STUDY 1

1. **e.** In cases of bladder wall thinning, even small perforations can lead to extravesical extravasation of mitomycin, secondary necrosis, and fistula formation. As such, prior to administration of mitomycin, a distention cystogram to rule out extravasation is wise. Withholding mitomycin is not unreasonable, but given the benefits, and initial treatment plan, proceeding with administration is desirable, if possible. Reducing mitomycin dose, or delaying dose for a short period of time, would not prevent extravasation if perforation is present.
2. **a.** The CT demonstrates a breach in the bladder wall with likely extravasation of mitomycin to the surrounding perivesical fat. Local inflammation is noted, without extension to the peritoneal space or local organs. In this case, as there is no urinary extravasation, a catheter does not need to be placed, and is likely to exacerbate local irritative symptoms. Supportive care and time will likely resolve the symptoms and allow healing, though this may require months for resolution.
3. **d.** While it is safe to proceed with administration of intravesical mitomycin upon bladder healing, despite previous complications, in this case the high-grade nature of the tumor and the presence of CIS make BCG induction a more rational approach, with greater likelihood of therapeutic efficacy. It is important to note that the administration of mitomycin does not preclude later BCG induction, but delayed healing of the bladder wall, and/or complications from mitomycin administration, may delay BCG instillation.

CASE STUDY 2

1. **a.** Systemic inflammatory symptoms commonly associated with BCG administration include low-grade fever, muscle aches, and chills that may start within 8 hours of administration and persist for 1–2 days. These symptoms are generally self-remitting, do not require BCG dose reduction, and can be managed by supportive care only. High fever, rigors, or hypotension, if occurring within hours of administration, should prompt emergent evaluation with suspicion for bacterial sepsis or systemic BCG absorption.
2. **d.** Severe local symptoms are common after administration of intravesical BCG, particularly after the patient has been sensitized to the mycobacterium through previous administration. Usually these symptoms are self-remitting if they are inflammatory in nature. Most will resolve in 2–3 days, allowing for repeat administration the following week. In those cases in which the symptoms persist for longer, a dose can be withheld, and upon readministration, dose reduction can be carried out. If symptoms persist, despite supportive care, for longer than 2–3 weeks, granulomatous cystitis should be considered and empiric antituberculous therapy should be implemented to prevent systemic dissemination and/or chronic bladder damage. Bladder biopsy may demonstrate granulomatous inflammation, but should primarily be used to rule out refractory, progressive malignancy, if suspected. Even if no granulomatous inflammation is noted on biopsy, empiric therapy should be considered on the basis of high clinical suspicion.
3. **e.** Given the history of BCG infection and granulomatous cystitis, additional BCG should not be considered in this patient, particularly given the absence of residual cancer. If recurrence were to be noted, alternate intravesical therapy, or cystectomy, should be considered.

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23 Complications of Renal Tissue Ablation

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CHAPTER OUTLINE

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KEY POINTS

1. Ablation therapy is being used with increasing frequency for renal masses.
2. Complication rates of renal mass ablation compare favorably to extirpative nephron-sparing surgery.
3. Patient and tumor selection are the most important factors to prevent complications.
4. The most common complications after percutaneous renal mass ablation are minor and include pain or paresthesia and asymptomatic hematomas.
5. Urinary tract injury is the most common major injury after radiofrequency or microwave ablation and is often managed with ureteral stenting or percutaneous drains.
6. Hemorrhage is the most common major injury after cryoablation. Larger tumors can be embolized preoperatively to limit the risk of hemorrhage.

Introduction

With the rise in diagnosis of incidental small renal masses, a shift in management of renal cell carcinoma (RCC) has emerged. Most notable is the increased utilization of nephron-sparing techniques. A recent publication based on the National Inpatient Sample showed that from 2005 to 2007 there was a 25% and 20% relative increase in the use of thermal ablation (TA) and partial nephrectomy (PN), respectively, while the use of radical nephrectomy (RN) had a 7% relative decrease.[1]

In 2009, the American Urological Association's (AUA) *Guideline for the Management of the Clinical Stage 1 Renal Mass* stated that for T1a renal lesions PN and RN are considered a standard of care (highest grade). TA is considered an option (lowest grade) for healthy patients and a recommendation (middle grade) for unhealthy patients. This conclusion, appropriate at the time of publication, stemmed from outcomes with increased risk of local recurrence and shorter follow-up.[2] More recent publications have improved our understanding of TA outcomes.

Psutka et al. reviewed 185 patients with cT1 RCC undergoing percutaneous radiofrequency ablation (RFA), with a median follow-up of 6.4 years.[3] They demonstrated 5-year cancer-specific survival (CSS) of 99% and local recurrence-free survival (LRFS) of 95%. Evaluating laparoscopic cryoablation (CA), 142 patients with cT1 RCC and a median follow-up of 92 months had 5-year CSS of 97% and LRFS

of 87%.[4] Given the indolence of many of the tumors, the CSS survival data are not surprising considering what we know about active surveillance in this population. More important, however, is the focus on local control. More recent studies, specifically focused in the RFA literature, have demonstrated that with refined preoperative tumor selection we can improve LRFS outcomes to approach those of partial nephrectomy.[5–7] With longer follow-up and improved oncologic outcomes, we anticipate increased utilization of ablative techniques in the management of renal masses. Therefore a thorough understanding of complications is critical to achieving excellent oncologic efficacy while minimizing morbidity.

Based on the aforementioned 2009 AUA Guideline, the morbidity of RFA and CA compares favorably with that of laparoscopic PN (LPN), a referent standard, in the context that LPN patients had similar sized tumors and were younger and, presumably, healthier.[2] To understand in further detail, the following chapter reviews the mechanism of action of ablative technologies, along with the prevention, frequency, and management of complications. Although RFA and CA are the most popular modalities used, newer modalities, including microwave ablation (MWA) and irreversible electroporation (IRE), are also discussed.

Prevention of Complications

Many factors play into complication risk during and after ablation. Most important is choosing appropriate patients who have a high probability of success with a low risk of complications. However, there are instances where higher-risk patients or tumors have ablation as a solitary option. In this scenario adjunct procedures, such as preoperative angioembolization, hydrodisplacement, and cold pyeloperfusion can help minimize complications.

PATIENT SELECTION

Patient selection plays the largest role in preventing complications. While it is generally understood that larger tumors, tumors closer to renal sinus, and tumors close to important structures are most at risk of complications, quantifying that risk can be difficult.

The RENAL nephrometry score (Radius, Exophytic/Endophytic, Nearness to the collecting system or sinus, Anterior/posterior and Location relative to polar lines) was developed to standardize renal tumor size, location, and depth[8] and has been shown to correlate with complications after PN.[9] Subsequent work by Schmit and colleagues compared RENAL nephrometry scores to complication rates in patients undergoing percutaneous ablation (RFA or CA).[10] In 627 patients (751 tumors) there was a significant association between higher RENAL nephrometry score and major complication (≥Clavien III) risk, with low- (RENAL 4–6), moderate- (RENAL 7–9), and high-complexity (10–12) major complication rates of 3.4%, 5.4%, and 15.9%, respectively ($p < 0.001$). Overall, major complications occurred in 7.8% of CA, but only 2.7% of RFA. They did not do independent analysis on type of TA, and, therefore, their finding might be dominated by CA alone. Similar results correlating RENAL nephrometry score and CA complications were also confirmed in another series.[11]

In contrast, Seideman et al. found no association between RENAL nephrometry score and risk of complications in 199 RFA procedures (2.0% Clavien grade III–IV).[12] They argued that additional factors related to the type of TA could affect complication risk. For example, most CA probes and some RFA probes must puncture through the tumor, while the RFA probe used in their series deploys small 25G tines into the tumor, potentially minimizing trauma. Other potential reasons why no association was seen could be that the standard RENAL nephrometry score does not capture size differences between tumors that are generally <4 cm. A more discerning tool might be the modified RENAL nephrometry score, which has shown improved correlation with oncologic outcomes.[6]

Specifically evaluating laparoscopic CA, Lagerveld et al. differentiated risk factors for both intraoperative and postoperative complications.[13] They concluded that intraoperative complications are significantly associated with tumors >3.5 cm, which appears to predict complications better than RENAL nephrometry score. Regarding postoperative complications, only the N (nearness to collecting system) portion of the RENAL nephrometry score was predictive of complications.

Both RFA and CA can be used to treat exophytic as well as completely endophytic renal masses. Selection of the approach (laparoscopic versus percutaneous) depends on tumor location, patient's health status, and the surgeon's expertise. At our center, we use TA to treat tumors of <3–4 cm that typically have a peripheral component allowing percutaneous access. Laparoscopic or robot-assisted TA is rarely recommended. We believe the energy source chosen should be based on physician preference, and we solely use RFA given our comfort and experience with the modality. More endophytic tumors might have the benefit of ice ball monitoring with CA, although outcome differences have not been reported in the literature.

Historically, contraindications to percutaneous TA have included tumors adjacent to the renal pelvis or ureter, or near important structures (bowel, liver, spleen, etc.). However, more advanced work with hydrodisplacement has made these relative contraindications.

PREOPERATIVE ANGIOEMBOLIZATION

Initially described to minimize the heat-sink effect in RFA,[14] preoperative tumor angioembolization has more recently been utilized to limit complications with CA. CA carries an increased risk of hemorrhage, especially in larger tumors, due to renal capsule fracture. In addition, unlike RFA, freezing of a tumor does not have inherent coagulative effects and likely causes a local coagulopathy with regard to platelet function.[15] Woodrum and colleagues embolized 40% (4/10) of tumors ≥5 cm that underwent CA.[16] The decision to undergo embolization was based on central involvement of the tumor, number of probes needed to treat the tumor, and tumor vascularity. There was no difference in mean tumor size between the embolization group (6.2 cm) and the no embolization group (5.7 cm, $p = 0.26$). Mean hematoma volume in patients who underwent preoperative embolization was 18 mL, compared to 357 mL in patients

who did not ($p < 0.001$). Clinically, this translated into no blood transfusions in the embolization group, and one transfusion (17%) in the no embolization group. This study was retrospective and small, but certainly suggests that utilizing preoperative embolization in large tumors can decrease the risk of hemorrhage. Further work on embolization from the same institution shows increased utilization in larger tumors: 15% of cT1b patients[17] and 58% of cT2 patients underwent preoperative embolization.[18]

Similar results were found by Miller et al., who reviewed their small series of 21 tumors.[19] Four tumors (mean 4 cm) were treated preablation with embolization and had no complications. In contrast, the remaining 17 tumors (mean 3.6 cm) had an 83% complication rate, including a 41% hemorrhage rate. Although their study lacked granularity with regard to blood transfusions, they concluded preablation embolization reduces the risk of hemorrhage.

We do not use angioembolization in our practice, as we prefer to treat larger tumors that might benefit from angioembolizaiton prior to CA with either partial or radical nephrectomy. If thermal ablation is performed in a larger tumor (>3–4 cm), we prefer to use RFA as it is coagulative, precluding the need for angioembolization.

HYDRODISPLACEMENT

All forms of TA risk injury to nearby structures, and it is generally accepted that structures within 1 cm of a renal lesion are most at risk. Colon is most commonly involved, but abdominal wall, small intestine, ureter, and psoas muscle are also encountered. Hydrodisplacement prior to ablation was first described by Farrell and colleagues, who used sterile water to displace bowel prior to RFA (Fig. 23.1).[20] This technique involves fine needle placement in a plane between the tumor and structure, with instillation of fluid. Typically, 5% dextrose or sterile water are used, although iodinated contrast material has been described to better illuminate the infusion on cross-sectional imaging.[21] It is best to avoid saline if performing RFA due to the risk of ionic transmission of energy.

The type of thermal ablation should not affect the success of hydrodisplacement; studies have shown 96% success (50 of 52) prior to CA[22] and 96% success (53 of 55) prior to RFA.[23] More contemporary series have demonstrated that hydrodisplacement was used prior to 12–14% of RFA procedures.[24,25] It is less frequently described in CA series, except in procedures involving large (cT1b/cT2) tumors, where it was used 35–42% of the time.[17,18]

In our experience, tumors that lie in close proximity to critical structures often gain enough separation just by positioning the patient prone or lateral decubitus. Hydrodisplacement is infrequently needed, but often successful when used. We find the greatest success when displacing colon or small intestine. The ureter can be more difficult to move; tumors in close proximity to the ureter are more commonly referred for partial or radical nephrectomy.

PYELOPERFUSION

For tumors that lie close to the ureter or collecting system, prior investigations have looked at retrograde ureteral infusion of cold fluid. The first description of this technique during RFA was by Wah and colleagues in 2005.[26] They published a case report with retrograde infusion of 5% dextrose solution cooled to 6°C at a pressure of 80 cm of H_20 for a 2-cm centrally located tumor. The infusion was through a 7F pigtail catheter placed endoscopically into the renal pelvis and subsequently removed 48 hours after the procedure. Just as in hydrodisplacement, a nonionic solution was used due to theoretical concerns about energy transmission. The patient recovered well without any collecting system or ureteral damage.

They followed this initial investigation by publishing results of their pilot study, comprising 17 patients with 19 tumors that were within 1.5 cm of the ureter.[27] No complications occurred, and no patients developed urinary fistulas

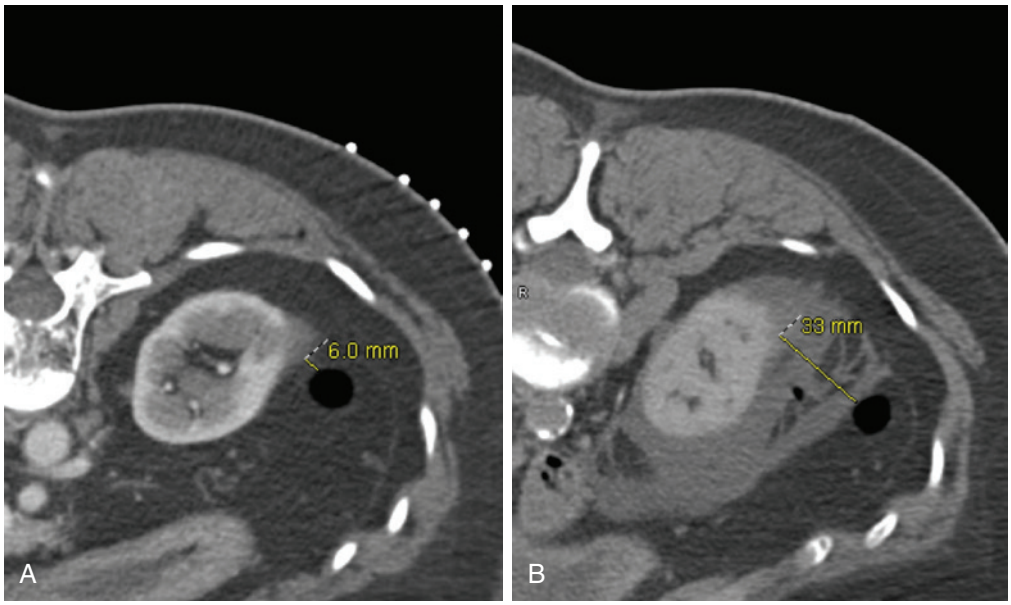


Figure 23.1 CT scan showing left colon pre- (A) and post- (B) hydrodisplacement with D5 water away from renal mass.

or ureteral strictures. Although there is the potential to cause a heat sink with cold pyeloperfusion, there were no local recurrences during their follow-up period. The most recent series by Wah et al. utilized this technique in 6.2% (13/210) of RFA procedures.[24]

Complications of Ablation

RADIOFREQUENCY ABLATION

Radiofrequency ablation can be performed either laparoscopically or percutaneously. The main difference with respect to complications relates to the need to mobilize colon and/or small intestine and expose the tumor to perform the ablation laparoscopically. These portions of the procedure have expected risks that are no different than a laparoscopic radical or partial nephrectomy. Specifically related to the ablation portion of the procedure, most complications are related to thermal injury.

The 2009 AUA Guideline meta-analysis lists major urologic complications including hemorrhage requiring transfusion or other intervention, urinary leak or fistula, and loss of kidney function, among others. The major RFA complication rate was 6% (range 4.4–8.2%), not significantly different than CA.[2] Comparing studies is often difficult due to different terminology, different grading criteria, and lack of granularity. A contemporary list of RFA studies with complications are summarized in Table 23.1. Ranges for minor Clavien grade I complications, grade II complications, and major grade III–V complications were 5–19%, 1–8%, and 2–10%, respectively. Specific complications are discussed below.

Mechanism of Action

Radiofrequency ablation uses a monopolar alternating electrical current using the frequency within the radio segment of the electromagnetic spectrum. The current flows between the grounding pad and the RFA probe. Heat is generated as a result of ionic agitation of the tissue around the probe, and cell death is achieved when the temperature within a tumor and a small rim of the surrounding tissue rises to 60°C. High temperatures produce occlusion of the microvasculature and destruction of the cellular cytoskeleton, causing tissue ischemia and impaired DNA replication, and ultimately resulting in a predictable zone of coagulation necrosis around the radiofrequency electrode.[28]

During RFA tissue temperatures generally reach >100°C. In addition to causing cell death, heating also has inherent coagulant properties to limit the risk of hemorrhage.

Urinary Tract Injury

Typically, the most common major injury with RFA is to the urinary tract, either the collecting system or ureter (Fig. 23.2). In a porcine model, Brashears et al. demonstrated that after causing direct damage to the collecting system, four of seven RFA procedures resulted in urinary fistula. In contrast, after 15 direct cryoablation procedures to the collecting system not a single fistula developed.[29]

Table 23.1 Complications of Radiofrequency Ablation

Study (year)	No. Patients/ Procedures	Approach	Tumor Size (mean, cm)	Hydrodisplacement	Pyeloperfusion	Clavien I	Clavien II	Clavien III/IV	Blood Transfusion	Urinary Tract Injury
Iannuccilli et al. (2015)[25]	203/203	Perc	2.5	28 (13.8%)	–	22 (10.8%)	0	8 (3.9%)	0	7 (3.4%)
McClure et al. (2014)[30]	84/115	Perc	2.6	–	–	11 (9.6%)	1 (1.2%)	3 (2.6%)	1 (1.2%)	2 (2.4%)
Lorber et al. (2014)[52]	53/53	29 Perc/ 24 Lap	2.3	–	–	10 (18.9%)	4 (7.5%)	0	–	–
Wah et al. (2014)[24]	165/210	Perc	2.9	26 (12.4%)	13 (6.2%)	12 (6.7%)	0	9 (4.3%)	0	7 (3.3%)
Ramirez et al. (2014)[53]	79/79	Lap	2.2	–	–	4 (5.1%)		3 (3.8%)	0	3 (3.8%)
Seideman et al. (2013)[12]	199/199	170 Perc/ 29 Lap	2.4	–	–	10 (5.0%)		4 (2.0%)	–	–
Balageas et al. (2013)[31]	62/62	Perc	2.3 (median)	–	–	–	–	6 (9.7%)	1 (1.6%)	3 (4.8%)
Atwell et al. (2013)[54]	222/232	Perc	1.9	–	–	–	3 (1.3%)	7 (3.0%	–	4 (1.7%)
Atwell et al. (2012)[15]	–/254	Perc	2.1	–	–	13 (5.1%)	3 (1.2%)	9 (3.5%)	–	6 (2.4%)

Perc, percutaneous; Lap, laparoscopic

Although most urinary tract injuries lead to major complications, studies have described minor complications including a single episode of urine leak (0.9%)[30] and two ureteral strictures (1.0%)[24] managed conservatively. More commonly, injury to the urinary tract is a grade III complication as it requires either ureteral stenting or percutaneous drainage, and has been described in 1.7–4.8% of cases.

Hemorrhage

As stated before, the risk of bleeding after RFA is low given the coagulative properties of heating tissue. However, many studies describe minor Clavien grade I complications of perinephric hematoma after RFA (Fig. 23.3) without subsequent transfusion, up to 14.5% of cases.[31] More importantly, the need for blood transfusion (grade II) or subsequent angioembolization (grade III) is an infrequent event in most RFA series (0–1.6%).



Figure 23.2 Delayed phase of CT showing urine leak after radiofrequency ablation of right renal mass.

Pain/Neuropathy

A common minor grade I complication after RFA is pain or neuropathy. Baker et al. noted the correlation between pain after RFA and distance of the renal tumor to body wall musculature.[32] Reports of significant pain or nerve injury were made in most series, with the highest incidence in 3.9% of cases.[15] However, as described in their report, 90% of these patients had resolution of their symptoms within 6 months.

Pneumothorax

Pneumothorax in RFA is typically either related to the probe traversing the pleural cavity, or diaphragmatic injury during laparoscopy. Seideman et al. described a single case of pneumothorax that required needle decompression (grade III, 0.5%),[12] while most other series described minor grade I pneumothoraces that were managed conservatively (up to 4.8%).[31]

Other

Damage to colon or small intestine are rare complications of RFA. In the contemporary studies listed, only one patient (1.6%) experienced a duodenal perforation, which was reported by Balageas et al.[31]

CRYOABLATION

Like RFA, contemporary cryoablation (CA) is performed either laparoscopically or percutaneously, and complications due to laparoscopic CA are related to mobilization of the colon and nearby structures and exposure of the tumor. In this section, we focus on complications specific to the ablation itself.

The 2009 AUA Guideline meta-analysis lists major urologic complications from CA of 4.9% (3.3–7.4%), not significantly different than from RFA.[2] Like RFA, major complications analyzed in this meta-analysis include hemorrhage requiring blood transfusion and/or interventions and urinary tract injury. With CA, and as many highlighted studies show, the most concerning complication is the risk

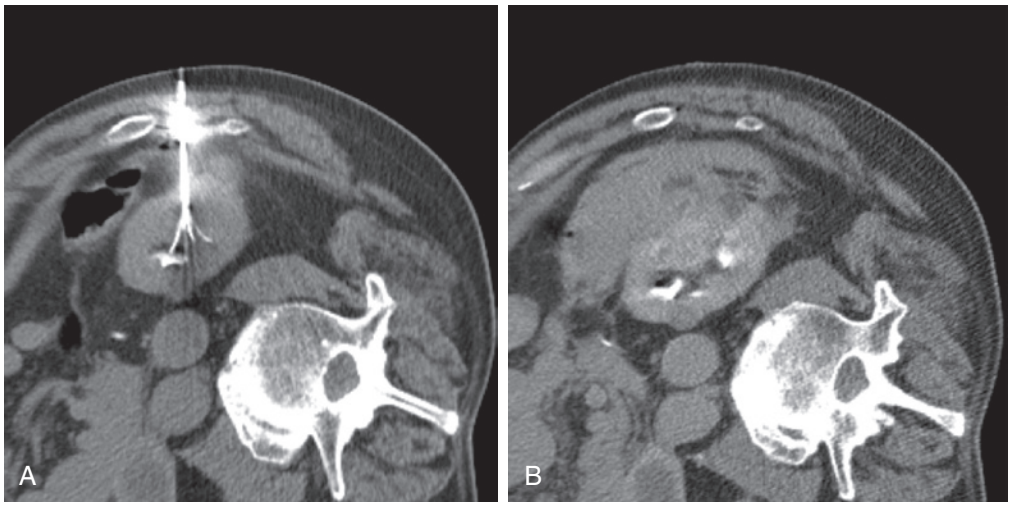


Figure 23.3 CT demonstrating probe placement during radiofrequency ablation of left renal mass (A), and perinephric hematoma on immediate postablation imaging (B).

Table 23.2 Complications of Cryoablation

Study (year)	No. Patients/ Procedures	Approach	Tumor Size (mean, cm)	Preoperative Embolization	Hydrodis-placement	Clavien I	Clavien II	Clavien III/IV	Blood Transfusion	Urinary Tract Injury
Caputo et al. (2015)[4]	138/138	Lap	2.4	––	–	8 (5.8%)	2 (1.4%)	5 (3.6%)	3 (2.2%)	–
Atwell et al. (2015)[17]	46/46	Perc	4.8	7 (15%)	16 (35%)	1 (2.0%)	3 (6.5%)	4	2 (4.3%)	0
Moynagh et al. (2015)[18]	12/12	Perc	8.4	7 (58.3%)	5 (42%)	1 (8.3%)	6 (50%)	2 (16.7%)	3 (25%)	0
Zargar et al. (2015)[37]	412/–	137 Perc	2.2 (median)	–	–	9 (6.6%)	0	1 (0.7%)	–	–
		275 Lap	2.5 (median)	–	–	8 (2.9%)	7 (2.5%)	5 (1.8%)	7 (2.5%)	1 (0.4%)
Larcher et al. (2015)[38]	174/–	Lap	2.0 (median)	–	–	16 (9.0%)	25 (15%)	5 (3%)	14 (8.0%)	–
Kim et al. (2014)[40]	263/–	145 Lap	2.4	–	–	1 (0.7%)	3 (2.1%)	1 (0.7%)		–
		118 Perc	2.7	–	–	–	2 (1.7%)	1 (0.8%)	2 (1.7%)	1 (0.8%)
Emara et al. (2014)[55]	56/56	Lap	2.6	–	–	3 (5.4%)	1 (1.8%)	1 (1.8%)	0	1 (1.8%)
Atwell et al. (2013)[54]	163/176	Perc	2.3	–	–	–	4 (2.3%)	5 (2.8%)		–
Breen et al. (2013)[39]	147/153	Perc	3.3	–	75 (49%)	9 (5.9%)	1 (0.7%)	6 (3.9%)	1 (0.7%)	3 (2.0%)
Blute et al. (2013)[11]	139/–	Perc	2.4	–	–	15 (10.8%)	3 (2.2%)	0	0	0
Atwell et al. (2012)[15]	–/311	Perc	3.2	12 (3.9%)	–	15 (4.8%)	10 (3.2%)	16 (5.2%)	4 (1.3%)	0

of hemorrhage due to ice ball–induced renal capsule fracture and local coagulopathy.

A contemporary list of CA studies is listed in Table 23.2. For the purposes of summarizing these findings, the 2015 studies by Atwell et al.[17] and Moynagh et al.[18] are excluded because of the size of the tumors treated being discordant from general practice. Minor grade I complications were reported in up to 11% of cases, while grade II complications were reported in 1–15% of cases. Major complications (Clavien grade III or IV) ranged from 1% to 5% in most series.

Mechanism of Action

Cell death secondary to rapid severe freezing occurs by several mechanisms. Extracellular ice formation results in movement of water out of the cell and leads to changes in intracellular pH, protein denaturation, and mechanical disruption of the plasma membrane followed by intracellular ice formation.[33] Delayed tissue effects are caused by injury to the microvasculature resulting in tissue hypoxia, endothelial cell damage, edema, platelet aggregation, and thrombosis, and these delayed tissue effects culminate in coagulative necrosis.[34] Apoptosis and gene-regulated cell death have also been identified as other mechanisms of tissue disruption following freezing.[35]

It is generally accepted that a temperature of −40°C must be achieved to ensure cytotoxic effects of CA. Animal studies have shown that a double freeze cycle creates a larger cryolesion as compared to a single freeze.[36] It is not clear whether passive thawing between freezing cycles has greater tissue effects than active rapid thawing. However, it is generally accepted that a double freeze-thaw cycle with ice ball extension beyond the tumor margin should be used in clinical practice.

Hemorrhage

Some studies did not report the incidental finding of an asymptomatic perinephric hematoma, due to its low clinical significance. In those that did, the highest reported rate was 6.6% in the percutaneous series by Zargar et al.[37] For

percutaneous series the frequency of blood transfusion in the setting of a retroperitoneal hematoma ranged from 0.7% to 3.2% as noted by Atwell et al.[15] For laparoscopic CA most studies ranged from 1.4% to 2.5%, although Larcher et al. reported an 8% blood transfusion rate in their series of 174 patients.[38]

Even more concerning is the rate of angiography with possible embolization for patients with significant hemorrhage. Atwell et al. reported that 3.2% of patients undergoing percutaneous cryoablation required angiography due to Clavien grade III hemorrhage.[15]

Urinary Tract Injury

In contrast to RFA, the risk of urinary tract injury after CA is considerably lower. Zargar et al. reported one patient (0.4%) with urine leak requiring stent placement after undergoing laparoscopic cryoablation.[37] Breen et al. reported a slightly higher rate in their percutaneous CA series of 2.0% (n = 3) in their 153 patients.[39]

Pneumothorax

Although rare, Breen et al. reported a 2.6% (n = 4) rate of pneumothorax managed conservatively in their percutaneous series of 153 patients,[39] and Blute et al. noted a 3.6% rate (n = 5) in their percutaneous series of 139 patients.[11] Clinically significant pneumothoraces requiring chest tubes were recorded in 0.7% of a laparoscopic series[37] and 1.3% of a percutaneous series.[39]

Other

Pain and/or nerve injury was a fairly rare complication of CA, reported in only 0.6% of procedures by Atwell and colleagues. Regarding the rare complication of tumor track seeding, that same series only reported one case (0.3%).[15] No other large contemporary series reported track seeding.

Injury to colon or small intestine is relatively rare and was reported in 2.2% (n = 3) of patients by Blute et al.[11] All three were managed conservatively with no long-term complications. Kim et al. reported a single patient (0.7%) who had a duodenal and ureteral injury managed only with percutaneous drains.[40]

MICROWAVE ABLATION

Like the other thermal modalities discussed, microwave ablation (MWA) can be performed laparoscopically or percutaneously. This section focuses on complications related to the modality itself.

MWA is a heating technology so major complications can be viewed similarly to RFA. As one of the newer ablative technologies, all of the current literature is based on single-center series of <100 patients. In addition, many clinicians are learning this newer technology. Therefore one must take into account patient and tumor selection (size, location, depth) in assessing complications listed.

Seven studies were selected for review (Table 23.3). Number of patients per study ranged from 10 to 65, with most tumors cT1a. Studies had various methods of reporting tumor location and depth, so comparison of complication rates between studies is not feasible. Minor grade I, grade II, and major grade ≥III complication rates were 7–20%, 2–3%, and 2–20%, respectively.

Mechanism of Action

The utilization of electromagnetic microwaves to generate heat was popularized with the domestic microwave oven in the 1960s. The technology stems from using radiofrequency waves (900–2500 MHz) to induce oscillation of water molecules in tissue, leading to heat formation. Early MWA systems struggled with bulky coaxial cables because of inadvertent heat and power loss. The antenna also risked increased power loss as its diameter decreased in size, bringing concerns about treatment efficacy. Newer generation microwave machines utilize gas or liquid cooled antennae that help to minimize power loss, with a resultant increase in tissue temperature and ablation zone size.[41]

Unlike RFA, which relies on the conduction of electrical current through tissue, electromagnetic microwaves can propagate irrespective of tissue conductance. One notable area of clinical relevance is in dealing with tissue charring. With RFA if tissue is heated too quickly char forms, increasing tissue impedance and limiting ablation size. With MWA, tissue can be heated quickly and with much higher temperatures. This makes MWA cycles considerably shorter than RFA, with higher temperatures.[41]

Multiple microwave probes can be used simultaneously and act synergistically, similar to CA, which gives the potential to treat larger tumors.[42] With respect to the kidney, higher treatment temperatures can also potentially better overcome the risk of heat sink seen with other ablation modalities.[41]

Hemorrhage

Similar to RFA, heating tissue with electromagnetic waves provides inherent coagulative properties to limit the risk of hemorrhage. Hematoma and blood transfusion were only encountered in the study by Moreland et al., which treated 53 patients with percutaneous MWA.[43] The one patient who required a blood transfusion (1.9%) had a delayed bleed on postoperative day 10, likely due to resumption of anticoagulation medication from an underlying comorbidity. No other study reported bleeding complications, and we conclude that in this early phase of study MWA has a low risk of hemorrhage when treating small renal masses.

Urinary Tract Injury

Urinary tract injury was the most frequent major complication encountered (1.5–20%). The high complication rate noted in Castle et al. (20%) relates to their small series, larger tumor size (mean 3.65 cm), and tumor depth with 50% of the tumors abutting the urinary tract. The complications included one patient who developed a postoperative urinoma, and another patient who had a retained foreign object, likely from the microwave needle, causing ureteropelvic junction obstruction and subsequent radical nephrectomy.[44] Two other studies described patients with urinary fistula, one (1.5%) resolved without any further treatment[45] and one (2.1%) that ultimately led to a nephrectomy due to abscess formation.[46]

Other

Most complications related to microwave ablation were minor (Clavien grade I). Reviewed studies demonstrated the most frequently reported complication of flank site pain and

Table 23.3 Complications of Microwave Ablation

Study (year)	No. Patients/ Tumors	Approach	Tumor Size (mean, cm)	Hydrodisplacement	Clavien I	Clavien II	Clavien III/IV	Blood Transfusion	Urinary Tract Injury
Moreland et al. (2014)[43]	53/55	Perc	2.7 (median)	20 (38%)	4 (7.5%)	1 (1.9%)	0	1 (1.9%)	0
Yu et al. (2014)[45]	65/69	Perc	2.7	–	0	2 (3.1%)	0	0	1 (1.5%)
Horn et al. (2014)[47]	14/15	Perc	2.0	–	0	0	1 (7.1%)	0	0
Guan et al. (2012)[46]	48/48	28 Lap/20 open	3.1	–	4 (8.3%)	1 (2.1%)	1 (2.1%)	0	1 (2.1%)
Castle et al. (2011)[44]	10/10	3 Perc/7 Lap	3.65	–	2 (20%)	–	2 (20%)	0	2 (20%)
Bai et al. (2010)[56]	22/23	Lap	2.8	–	4 (18.2%)	0	0	0	0
Carrafiello et al. (2010)[57]	12/12	Perc	2.0	–	1 (8.3%)	0	0	0	0

or numbness (8.3–18.2%), likely due to thermal injury to musculature or retroperitoneal nerves.

The only other notable complication in this early collection of studies was a single pseudoaneurysm identified immediately after ablation that required embolization.[47] These authors noted that of the 14 patients undergoing ablation, this was the largest tumor in their series (3.9 cm). Arteriovenous fistulas and pseudoaneurysms are known, but not well understood, risks of nephron-sparing procedures and likely relate to microvascular procedural trauma. To our knowledge, this is the only report of pseudoaneurysm after microwave ablation and further literature will better define its accepted risk.

IRREVERSIBLE ELECTROPORATION

Mechanism of Action

Since the 1970s researchers have utilized low-voltage electrical current to induce reversible poration in cellular membranes, which can aid in drug delivery and gene therapy. More recent investigations by Rubinsky and colleagues augmented the impulses and recognized that a higher voltage and a greater number of impulses can lead to irreversible electroporation and subsequent apoptosis. What they found was a reproducible, relatively nonthermal area of tissue necrosis.[48] Given the decreased risk of thermal injury, irreversible electroporation (IRE) has a different complication spectrum compared to the other forms of thermal ablation.

Overview of Complications

The first study to describe human applications of IRE for RCC utilized the technology prior to curative extirpation in five subjects.[49] The only intraoperative complication was a single case of supraventricular extrasystole. The electrical impulses are gated to an electrocardiogram to prevent cardiac arrhythmias, so it is unclear the etiology of this finding. No postoperative complications were noted.

At the time of publication, there is only one manuscript describing outcomes after percutaneous IRE for small renal masses.[50] Trimmer et al. published their series of 20 renal masses undergoing IRE, with mean tumor size of 2.2 cm. They described seven minor (Clavien grade I) complications and no major complications. The most common complication was seen in three patients with postoperative urinary retention (15%), likely related to anesthesia. Two patients required increased pain control (10%). The last two patients (10%) had small asymptomatic retroperitoneal hematomas that were noted on immediate postprocedure imaging and required no further management. No blood transfusions, urinary tract injuries, or delayed complications occurred. Prior animal models have shown that IRE spares connective tissue structures, thereby limiting potential damage to nerves, vasculature, and collecting system.[51] This might explain the lack of complications in this initial small series, although larger series are needed to confirm this finding.

Managing Complications of Ablation

HEMORRHAGE

Most perinephric hematomas following percutaneous ablation are diagnosed using the immediate postablation imaging done to document the adequacy of ablation. These are usually small and often are not clinically relevant. However, severe hemorrhage can occur. Significant bleeding causing hemodynamic instability can be treated by selective embolization of the bleeding vessel. Patients with large hematomas but stable vital signs can be treated conservatively with strict bed rest and frequently repeated blood counts. Specifically related to CA, injecting a hemostatic agent into the cryoprobe tract following ablation can lower the risk of hemorrhage.

Bleeding after laparoscopic CA is frequently due to premature needle extraction and renal parenchymal fractures, which can be prevented by ensuring that cryoneedles enter the tumor at a right angle. It is important to wait until the thawing is complete before attempting to remove the cryoneedle to avoid large cracks in the tumor or renal parenchyma. If bleeding occurs, hemostatic agents can be placed into the defect and are often sufficient to achieve hemostasis. As stated previously, hemorrhage following laparoscopic

RFA is uncommon because RFA effectively coagulates the vessels within the tumor and a rim of normal parenchyma.

URINARY TRACT INJURY

Urine leaks following ablation result from either direct calyceal puncture or unintended extension of the ablation zone into the collecting system. If urine leak is suspected, CT of the abdomen with IV contrast is usually diagnostic and will show contrast extravasation into a perinephric urinoma. In patients with renal insufficiency or contrast allergy, antegrade or retrograde pyelography can help establish the diagnosis. Treatment consists of draining the collecting system percutaneously or with a ureteral stent for 4 to 6 weeks as most leaks will seal by that time.

A ureteral stricture or ureteropelvic junction obstruction is typically diagnosed clinically by flank pain, or hydronephrosis on imaging. Significant obstruction can be managed acutely with a ureteral stent or percutaneous nephrostomy tube. Long-term cure with a pyeloplasty or ureteroureterostomy, depending on the location of the obstruction, can be done 6 weeks after ablation. We prefer to remove ureteral stents for at least 4 weeks prior to reconstruction to avoid significant periureteral inflammation. Percutaneous nephrostomy tubes can be used instead for patients with symptomatic obstruction prior to surgery.

PAIN OR PARESTHESIA AT THE PROBE INSERTION SITE

With CA, pain or paresthesia occurs secondary to cryoinjury to the sensory nerves at the body surface. The entire cryoneedle is cooled during CA; therefore, care must be taken to avoid freezing the skin at the insertion site. Placement of a warm, saline-soaked gauze around the cryoneedle is usually sufficient to prevent freezing of the skin. With RFA, the active portion of the probe is positioned within the kidney, but injury to the sensory nerves in the skin is possible if they are within the ablation zone. Track ablation is usually the final step of percutaneous RFA. It is used to decrease bleeding and prevent tumor seeding. The generator is activated as the probe is slowly withdrawn through the renal parenchyma and the perinephric fat. It is important to deactivate the generator before withdrawing the probe beyond Gerota's fascia because thermal injuries to psoas muscle can result in pain and paresthesias. Most of these are self-limited and will resolve after a few days. However, significant sensory or motor deficits may require a neurologic consultation.

INJURIES TO ADJACENT ORGANS

Injuries to the bowel and other adjacent organs are some of the most serious complications of renal ablation. Fortunately, as shown above, these complications are rare. During laparoscopic ablation, colon is usually reflected off the kidney before ablation. If the probe is positioned correctly and monitored carefully bowel injury should never be an issue. As a general rule, for percutaneous ablation the presence of bowel within 1 cm of the ablation zone that cannot be manipulated with changes in patient position or hydrodisplacement should preclude treatment.

CT of the abdomen and pelvis with oral contrast has very high sensitivity for diagnosis of a bowel injury and should be obtained immediately if suspected. If CT is indicative of a bowel perforation, an immediate exploration with bowel repair and/or resection is often necessary.

Pneumothorax can result from inadvertent lung injury during percutaneous insertion of an ablation probe. The diagnosis is made with a chest radiograph. Small pneumothoraces can be followed with repeated chest radiographs, and treatment with supplemental oxygen is frequently sufficient. However, large expanding pneumothoraces or those causing respiratory compromise will require a chest drain for resolution.

Conclusions

Both percutaneous and laparoscopic approaches with multiple ablation modalities are used to effectively treat renal masses with increasing frequency. Incidence of complications is favorable when compared to extirpative nephron-sparing surgery. Proper patient selection, careful preoperative planning, and meticulous technique will ensure excellent cancer control with minimal morbidity.

References

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Chapter 23 Questions

1. Which of the following renal mass characteristics is generally not a risk factor for ablation complications?
   a. Larger tumors
   b. Exophytic tumors
   c. Tumors close to renal sinus
   d. Tumors close to ureteropelvic junction
   e. None of the above

2. Literature has shown that RENAL nephrometry score correlates with complication risk for which treatment modality(ies)?
   a. Cryoablation
   b. Radiofrequency ablation
   c. Microwave ablation
   d. Irreversible electroporation
   e. Both a and b

3. Which adjunct preoperative procedure will decrease the size of retroperitoneal hematoma after cryoablation?
   a. Hydrodisplacement
   b. Pyeloperfusion
   c. Angioembolization
   d. Blood transfusion
   e. None of the above

4. Important structures within ___ cm of a renal mass should undergo hydrodisplacement prior to ablation.
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

5. Which type of fluid should be used for retrograde pyeloperfusion during thermal ablation?
   a. NaCl
   b. Lactated Ringers
   c. D5 H_2O
   d. Iodinated contrast
   e. Both a and b

6. Urinary tract injury is the most common major complication for which modality(ies)?
   a. Radiofrequency ablation
   b. Cryoablation
   c. Microwave ablation
   d. Irreversible electroporation
   e. Both a and c

7. Which of the following ablation modalities has the highest rate of blood transfusion?
   a. Radiofrequency ablation
   b. Cryoablation
   c. Microwave ablation
   d. Irreversible electroporation
   e. Both a and b

8. Which of the following is not a management option for postablation hemorrhage?
   a. Serial blood counts
   b. Bed rest
   c. Blood transfusion
   d. Percutaneous drain
   e. Angioembolization

9. Ureteral stents for urine leaks following ablation therapy should be kept in place for what length of time?
   a. 1 day
   b. 2 days
   c. 1 week
   d. 2 weeks
   e. 6 weeks

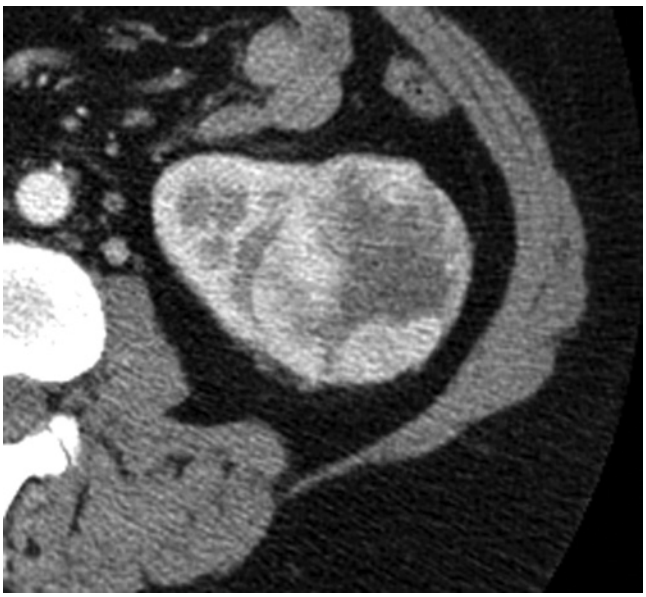
10. Renal mass distance from body wall musculature has been shown to correlate with postprocedural pain in which modality?
    a. Radiofrequency ablation
    b. Cryoablation
    c. Microwave ablation
    d. Irreversible electroporation
    e. None of the above

Case Studies

CASE 1

A 65-year-old unhealthy male with a 6-cm left renal mass extending into the renal sinus presents to your office (Case Fig. 23.1). His comorbidities make him a high-risk candidate for extirpative surgery. After a discussion of treatment options, he elects to proceed with percutaneous cryoablation.

1. Which of the following preablation procedures has been shown to limit the size of retroperitoneal hematoma?
   a. Blood transfusion
   b. Ureteral stent placement
   c. Pyeloperfusion
   d. Angioembolization
   e. Overnight admission with bed rest



Case Figure 23.1

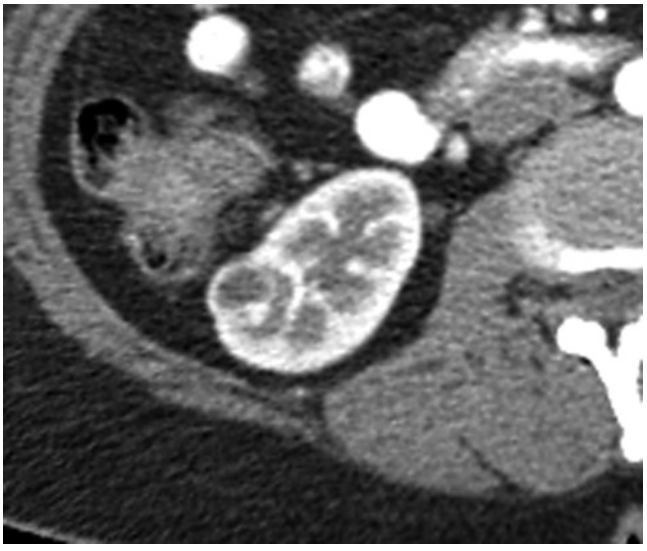
2. To limit the risk of skin freezing, what should be done prior to performing cryoablation?
   a. Body warmer
   b. Warm gauze surrounding cryoprobe
   c. Increase room temperature
   d. Only freeze to O°C
   e. Skin freezing is not a risk of cryoablation

3. Postoperatively the patient develops mild hematuria and flank pain. His hemoglobin decreases from 13 g/dL to 10 g/dL. His vital signs remain stable. A stat CT scan is performed and demonstrates a large retroperitoneal hematoma. Repeat hemoglobin and vital signs remain stable. What is the best next step?
   a. Bed rest
   b. Serial blood counts
   c. Angioembolization
   d. Open exploration
   e. Both a and b

4. The following morning, his urine becomes bright red and his flank pain worsens. His hemoglobin is now 7 g/dL. What is the best next step?
   a. Bed rest
   b. Serial blood counts
   c. Angioembolization
   d. Open exploration
   e. Both a and b

CASE 2

A 79-year-old healthy woman with a 1.5-cm right anterior renal mass in a solitary kidney presents to clinic (Case Fig. 23.2). She underwent left radical nephrectomy for renal cell carcinoma 15 years ago. You review the films and note that the tumor comes close to a calyx, and the right ascending colon is approximately 0.5 cm from the edge of the renal mass. Her creatinine is 1.8 mg/dL. After extensive discussion, she elects to proceed with percutaneous radiofrequency ablation.



Case Figure 23.2

1. What is the most common risk of her radiofrequency ablation (RFA) procedure?
   a. Small retroperitoneal hematoma
   b. Pneumothorax
   c. Track seeding
   d. Colon injury
   e. Urinary tract injury

2. Which of the following adjunct procedures should be performed prior to RFA?
   a. Preoperative embolization
   b. Ureteral stent placement
   c. Hydrodisplacement of ascending colon
   d. Pyeloperfusion
   e. None of the above

3. After successful RFA, she is discharged home the same day. She presents to the ER 1 week later with a temperature of 38.5°C and flank pain. You are concerned that she has a urine leak. What is the best next step?
   a. Computed tomography of the abdomen and pelvis with contrast
   b. Retroperitoneal ultrasound
   c. Magnetic resonance imaging of the abdomen and pelvis with contrast
   d. Cystoscopy with retrograde pyelogram
   e. Observation

4. For what period of time should she have urinary tract drainage?
   a. 1 day
   b. 1 week
   c. 2 weeks
   d. 6 weeks
   e. 26 weeks

Answers

1. **b.** Large tumors are a risk factor for bleeding complications. Tumors close to renal sinus risk bleeding and urinoma. Tumors close to the ureteropelvic junction risk ureteral stricture. An exophytic tumor, independently, is not a risk factor for complications.
2. **a.** Prior literature has shown that cryoablation complications correlate with RENAL nephrometry score, while radiofrequency ablation results are equivocal. Microwave ablation and irreversible electroporation complications have not been evaluated compared to RENAL nephrometry score.
3. **c.** Prior literature has demonstrated that angioembolization prior to cryoablation decreases the risk of retroperitoneal hematoma postoperatively.
4. **a.** One cm is considered the safe cutoff for nearby structures prior to thermal ablation. Hydrodisplacement would be the procedure of choice if a critical structure is less than 1 cm from the tumor.
5. **c.** Because of the potential to conduct current during radiofrequency ablation, non-ionic fluids should be used. Iodinated contrast would also not be ideal as it would appear on peri-ablation computed tomography,

which could distort probe placement. Therefore, D5H20 would be the best choice.

6. **e.** Injury to the urinary tract is the most common complication after both types of heat-driven thermal ablation. The most common major complication after cryoablation is bleeding.
7. **b.** Due to the bleeding complications related to cryoablation, it has the highest rate of post-operative blood transfusion.
8. **d.** Managing a patient with post-ablation hemorrhage should include bed rest, serial blood counts, and blood transfusions. In severe cases, angioembolization might be needed. Placing a percutaneous drain into a retroperitoneal hematoma would expand the potential space of the hematoma and is counterproductive to the tamponade the retroperitoneum provides.
9. **e.** Ureteral stents for retroperitoneal urine leak should be left in at a minimum of 4 weeks. Therefore, the best answer here is 6 weeks.
10. **a.** The distance from body wall musculature to the renal mass has been shown to correlate with pain after radiofrequency ablation.

CASE 1

1. **d.** For large renal masses prior to cryoablation, angioembolization has been shown to limit the size of retroperitoneal hematoma.
2. **b.** Skin freezing is a minor but common complication of cryoablation. Placing a warm gauze around the cryoprobe at the level of the skin will help to limit the risk of skin freezing.
3. **e.** For a stable patient with a retroperitoneal hematoma, bed rest and serial blood counts are an appropriate first step, with blood transfusions only as indicated for symptomatic anemia or blood counts below threshold levels. Mild hematuria and flank pain are expected post-operative symptoms, so angioembolization or emergent open exploration are too aggressive management strategies at this point, regardless of the size of the hematoma.
4. **c.** With more significant hematuria and a dropping blood count, this is now an indication to proceed with a more aggressive intervention. Angioembolization would be the preferred next step of the options provided.

CASE 2

1. **a.** The most common risk (both minor and major) of radiofrequency ablation is a small retroperitoneal hematoma. Pneumothorax, track seeding, and colon injury are all rare complications. Urinary tract injury would be the most common major injury.
2. **c.** Given the less than 1 cm proximity of the ascending colon, hydrodisplacement would need to be performed.
3. **d.** Given her elevated creatinine of 1.8, a cystoscopy with retrograde pyelogam would be the best choice.
4. **d.** If a urine leak is seen on retrograde pyelogram, ureteral stent drainage should be in place for 4–6 weeks. Leaving a Foley catheter for the first 24–48 hours would be a reasonable adjunct move to ensure decompression of the urinary system.

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24 Complications of Prostate Cryosurgical Ablation

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CHAPTER OUTLINE

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Patient Selection
Diagnosis of Localized Recurrence for Patients Undergoing Salvage Prostate Ablation
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Operative Considerations
Technical Advances in Technology That Help to Reduce Complications
Technical Considerations
Complications
Complication of Cryoablation
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Less Commonly Seen Complications
Rare or Anecdotal Complications
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KEY POINTS

1. Cryotherapy causes tissue destruction by freezing, and can cause lower urinary tract symptoms (LUTS) in a fashion similar to that seen after other prostate surgeries like transurethral resection of the prostate (TURP) or laser prostatectomy.
2. In order to optimize results, and minimize the complication rates, careful patient selection is necessary.
3. The incidence of complications is higher in the salvage cryoablation group as compared to the primary cryoablation group.
4. It is challenging to treat large prostate glands. Neo-adjuvant androgen deprivation therapy for size reduction of such glands may help with reduction of gland size but not with oncological outcomes.
5. Erectile dysfunction is one of the commonest complications of prostate tissue ablation, and is multifactorial in etiology.
6. Urethral warming reduces the risks of urethral slough, strictures, pain and incontinence with cryoablation.
7. Saline injection in the layers of the Denonvilliers fascia to cause a separation between the prostate and rectum may reduce the incidence of rectal injuries and fistulas in cryoablation.

Introduction

According to the Surveillance, Epidemiology, and End Results (SEER) Program data, the estimated number of new cases of prostate cancer in 2015 was 220,800, with an estimated death in 27,540 patients. Of the 10,018 patients from a CaPSURE study published in 2004, patients with prostate cancer underwent treatment with either brachytherapy, external beam radiation therapy, or cryoablation in 10.1, 12, and 2.8%, respectively.[1] The number of patients undergoing brachytherapy has since increased, and approximately 30% of patients undergoing radiation therapy will develop a biochemical failure or recurrence. Since salvage radical prostatectomy is a challenging procedure with high morbidity rates, the drive toward minimally invasive treatment of recurrent prostate cancer is increasing. Prostate cryoablation is now a reasonably well-established option for residual or recurrent cancer after primary nonexcisional treatment of prostate cancer. Experience with cryoablation has shown this to be minimally invasive and convenient, requiring short hospital stays, with many centers discharging patients the same day of the procedure. These features make the procedure an attractive choice, and the pool of patients has now been expanded to include even primary cases, in the nonsalvage setting.

Mechanisms of Tissue Injury and Causes of Complications

Prostate tissue ablation causes cell death by causing irreversible injury from nonphysiologic temperatures that are

not considered compatible with cell survival. In cryoablation cell damage is caused by intracellular ice formation, altered permeability of the cell membrane, and loss of cellular integrity. Factors that are important are intracellular ice formation, the final temperature achieved, and the rate of cooling.[2] Intracellular ice formation is very important and can be achieved either through multiple (double or even triple) freeze/thaw cycles[2] or by ensuring the right combination of cooling rate and end-point temperature.

In order to achieve optimal results, a good balance needs to occur between adequate freezing of tissues that need to be destroyed and cryoprotection of tissues that should not be frozen. This requires an accurate mapping of the extent of cancer, since a patient could potentially be cured without the risks of complications, if all of his cancer could be completely destroyed without any collateral damage. Focal cryoablations have lower complication rates compared to total cryoablation, and the incidence of incontinence, erectile dysfunction (ED), and fistula rates were higher in patients undergoing total cryoablation as compared to focal ablation (incontinence 13% vs 0%, ED 71% vs 100%, and fistula 4% vs 0%).[4]

Unfortunately focal ablations often undertreat cancers, since prostate cancer is known to be multifocal (79.5% of radical prostatectomy specimens),[5] and various studies have shown that biopsy often does not accurately map out the true extent of the disease. Many cancers are also found to be very close to the urethra, and one study reported that 66% of cases had foci of cancer within 5 mm of the urethra,[5] while another study showed actual urethral involvement in 17% of cases.[6] Also, apical cancers were seen in almost three-fourths of cases (74%) cases, and these tumors were more likely to be closer to the urethra.[6] Technical modifications aimed at reducing the cryo-injury to the urethra could cause undertreatment of these cancers, and many cryoablation failures typically occur in areas that get undertreated, like the prostate apex and the seminal vesical (SV).

Optimal cancer treatment thus requires a balanced approach, and the first step to minimizing complications would be to select patients appropriately.

Patient Selection

Appropriate case selection can go a long way in preventing (or minimizing) complications. In the absence of good diagnostic modalities that allow us to pinpoint the extent and sites of cancer in the prostate, we continue to rely on whole gland (or hemigland) ablation for cure.

The first aim of the treatment is to cure the patient of the cancer, and therefore it is essential to select patients with organ-confined disease. Patients with extraprostatic disease or those with SV involvement will have disappointing outcomes, since they will either have residual cancer or the ablation will have to be so aggressive and extensive that they will have higher risks of more serious complications.

Studies have confirmed this in the setting of primary cryoablation for clinical T3 disease with higher rates of biochemical failure than that after radical prostatectomy (RP) or radiation therapy (RT) in similar groups (biochemical failure seen in 48–52%[7,8]) and higher rectourethral fistula rates.[7]

For patients being considered for primary ablation, one should follow accepted parameters that define higher risk disease like prostate-specific antigen (PSA) levels, PSA velocities, biopsy parameters including volume of cancer, and Gleason scores. Patients with Gleason scores 8 or greater, tumor stage ≥T3, or those suspected of having LNI should be offered treatment, but with the knowledge that data on the use of cryoablation in these settings are not robust, although results from published series demonstrate effectiveness for high-grade disease.[7]

For patients undergoing salvage treatment, similar parameters have been studied. The following guidelines used for salvage radiation[9] have often been extrapolated for use in the salvage cryoablation setting: demonstration of localized recurrence with no evidence of distant metastases, time to recurrence after primary therapy of >2 years, PSA levels <10 ng/mL, PSA doubling time of >6–9 months, and a life expectancy >5–10 years.

In an effort to standardize the inclusion criteria for patients undergoing prostate focal therapy as part of clinical trials, a study panel has suggested the following criteria: PSA <15 ng/mL, clinical stage T1c–T2a, Gleason score 3 + 3 or 3 + 4, life expectancy of more than 10 years, and any prostate volume.[10]

DIAGNOSIS OF LOCALIZED RECURRENCE FOR PATIENTS UNDERGOING SALVAGE PROSTATE ABLATION

Dynamic magnetic resonance imaging (MRI) using diffusion-weighted imaging (DWI) or dynamic contrast-enhanced (DCE) MRI, and MR spectroscopy (MRS) can be used for assessment of local recurrence of prostate cancer. Combinations of DCE-MRI and DWI have a higher efficacy in detecting recurrence after RT.[11] Multiparametric (mp) MRI also has greater accuracy than T2-weighted imaging alone, for the detection of recurrent prostate cancer after RT.[12] Final confirmation of local recurrence is achieved through a prostate biopsy.

Prostate Biopsy

Doing targeted zonal or hemigland ablations when possible can help to minimize the risks of complications. However, it is important to map out the exact extent of the disease. Prostate biopsies are necessary, but there is a discordance between a conventional transrectal ultrasound (TRUS) guided biopsy and final pathology after radical prostatectomy. True unilateral cancer after radical prostatectomy was noted in only 28–29.3% of patients.[13,] In the lobe classified as benign on prostate biopsy, 5% cases even had T3 tumors noted after RP.[13,14]

More extensive biopsies and template saturation biopsies may be indicated for patients being considered for focal or hemiablative therapies, although data to support superiority of template biopsy remain limited.

MRI fusion biopsy is another technical advancement and has been included in the list of recommendations for the workup of patients undergoing focal therapy as part of clinical trials.[10] MRI with ultrasound fusion biopsy, identified 30% more high-risk cancers and 17% fewer low-risk cancers.[15] However, even with this advancement in technology, it is still possible for cancer to remain undetected on

an mpMRI, as exists the possibility of missing the target lesion on a fusion biopsy possibly from technical errors.[16]

Imaging and Other Tests for Staging

Conventionally, nuclear imaging with bone scans, computed tomography (CT) scans, and MRI have been used to assess the stage of the disease. The chances of these studies being negative even when there is occult metastases is high when the PSA is under 10 ng/mL, and many patients selected for either primary or salvage cryoablation have lower PSAs. The overall staging accuracy using current MRI protocols seems to be around 71–72%.[17] Studies using MRI have also shown that when a patient has either extraprostatic extension or SV involvement that is suspected on MRI, the chances of micro-metastases in lymph nodes as small as 0.8–1 cm in size is higher, especially when used in conjunction with other staging nomograms.[18] Micrometastases to lymph nodes could be predicted with a sensitivity and specificity of 100% and 65.2% for tumors that were T3a or more and 88.9% and 94.6% for T3b tumors using MRI.[17]

Thus, there may be a role for a pelvic lymph node dissection (PLND) in all patients suspected of having T3a disease or more on MRI. PLND can be done either by the conventional open technique or by laparoscopic or robotic-assisted laparoscopic technique. A conventional PLND may miss 13% of metastases that can occur outside of the drainage area,[19] and extended lymph node dissections may need to be done in selected cases. This may need to include the presacral nodes.[19]

Bone scans have a limited utility because of lower diagnostic yields in asymptomatic patients with PSA <10 ng/mL. The incidence of positive bone scans is higher with higher PSA levels, rising from 8% for PSA levels between 20 and 50 ng/mL to 40% for PSA >50 ng/mL.[20] MRI-DWI and 11C-choline PET/CT have also been shown to be useful for detecting bone metastases.[21] NaF PET/CT using 18F-sodium fluoride has shown some promise in detecting bone metastases from prostate cancer; whole-body DWI showed a higher specificity but lost some sensitivity when compared to 18F-NaF PET/CT.[22] It is possible that DW whole-body imaging may, in the future, be used to aid in the detection and/or follow-up of bone metastatic prostate cancer.

Operative Considerations

TECHNICAL ADVANCES IN TECHNOLOGY THAT HELP TO REDUCE COMPLICATIONS

Today's third-generation cryoablation devices have incorporated many technological advances that make the tissue injury more precise and controlled, thus reducing collateral damage. The first of these modifications is the use of an argon–helium gas combination to produce the freeze–thaw cycle. The use of multiple fine 17G cryoprobes can ensure delivery of well-controlled iceballs of 8–10 mm diameter, and improved glandular destruction has been shown to occur using a 6–8-probe technique compared to a 5-probe technique.[23] The use of transrectal ultrasound (TRUS) to monitor the iceball was developed by Onik et al.[24] and enabled a more accurate assessment of the extent of the "cryolesion." In order to decrease the effects on the urethra and minimize urethral slough a urethral warming device was later developed.[25] Efforts to minimize injury to the rectum were also described. Onik et al. found that raising the handle of the TRUS probe pushed the tip of the probe against the posterior rectal wall, thereby pulling the rectum off the prostate.[25] Developing further on this, Onik et al. subsequently created a mechanical separation between the rectum and prostate by injecting saline through the layers of the Denonvilliers fascia around the mid and apical regions of the prostate.[23]

TECHNICAL CONSIDERATIONS

Based on our experience with cryoablation, we feel that patients with uncontrolled bleeding diathesis or those on anticoagulant therapy can have significant bleeding and must be taken off these medications prior to surgery. These medicines can be resumed within 24–48 hours after the procedure or after the urine clears, whichever is earlier. A complete preoperative assessment includes a fitness for anesthesia. Many centers commonly do these procedures under general anesthesia, because of the ease, and often per patient's choice, but in patients with anticipated intubation difficulties, the procedure may be done under spinal anesthesia, and this choice is often run by the anesthesiology team. A limited bowel preparation may be used to ensure a rectum free of fecal matter at the time of the procedure, although we have not found this to be necessary or to add value and therefore use bowel preparations selectively. Antibiotics are used at the time of induction of anesthesia. Patients with tight urethral strictures may need an internal urethrotomy prior, since a Foley catheter is required to drain the bladder, and during the procedure a urethral warmer catheter is also used. Tight anal stenosis or a previous abdomino-perineal resection ending up with a closed anal orifice preclude placement of the transrectal probe. Transrectal ultrasound monitoring of the procedure is then not possible, and such patients are better managed by other modalities.

Patients with a very large prostate gland need multiple probes and are at risk for undertreatment. Neoadjuvant androgen deprivation therapy (NADT) may be useful in reducing the size of the gland (a mean reduction of 35% was noted) and a reduction of tumor volume by 50% that can occur within 2 months of therapy, although this rarely downstages the disease.[26] A more recent study with the use of NADT in men undergoing primary cryoablation showed that there were no significant differences in outcomes or complications between the groups except for patients in the intermediate-risk group, who showed better 5-year disease-free status.[27] We usually limit whole-gland treatment to patients with glands of 80 g or smaller and have also had good success with downsizing using luteinizing hormone-releasing hormone (LHRH) agonist therapy for 6 months in patients in whom the treatment delay is not believed to be consequential.

Our practice is to use two freeze–thaw cycles and monitor the ice ball formation with transrectal ultrasound. Temperature sensors are used at the apex, external sphincters, and neurovascular bundle (NVB). We also use the Onik maneuver of injecting saline between the layers of the

Denonvilliers fascia in order to cause a zone of separation between the prostate and the rectum (Fig. 24.1). After the procedure patients are discharged home the same day with a catheter, and we remove the catheter in 1 week.

Complications

Complications after prostate tissue ablation occur due to thermal damage to the prostate and surrounding tissues and are similar in patients undergoing cryoablation. They present as troublesome lower urinary tract symptoms or incontinence, sexual dysfunction, and/or as injury or damage to adjacent organs/tissue. The complication rates have been reported in a variable manner in the literature. The maximum variability seen is in the way ED and incontinence are reported. It is not uncommon for ED to be reported only in the group of patients who were previously potent before the initiation of treatment. The International Index of Erectile Function (IIEF-15) and the shortened version the Sexual Health Inventory for Men (SHIM) are two standardized questionnaires that are used, but these have limited utility in men who are not sexually active. A lot of variability is also noted in the way incontinence is reported, and this causes difficulties in comparison of results among studies. With prostate cancer, it is also important to consider the concept of "trifecta," since the biochemical progression-free survival (BPFS) is also important. It is technically possible to have a lower complication rate, as can be seen with focal ablation, and the tradeoff would be a higher BPFS.[4]

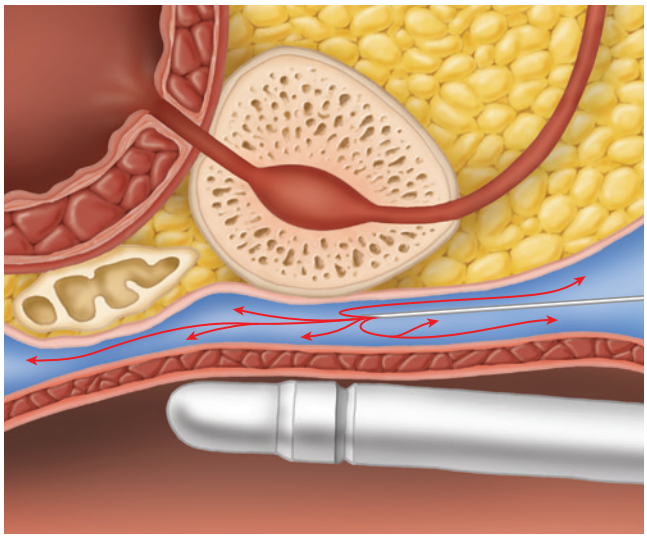


Figure 24.1 Saline hydrodissection into the space between Denonvilliers fascia and anterior rectal wall.

COMPLICATIONS OF CRYOABLATION

We queried the Cryo Online Data Registry (COLD) in addition to a review of literature for complications. As of December 6, 2015, the COLD registry had data from 39 sites, and 10 of these were academic centers. Records of 6771 cases were available, and of these 4102 patients underwent primary whole-gland ablation, and another 1011 patients had primary partial ablation. The remaining cases were either salvage whole/partial ablations or repeat ablations.

Commonly Seen Complications

Erectile Dysfunction

INCIDENCE. Erectile dysfunction was one of the most commonly seen side effects of cryoablation. The incidence of ED varies from 23.1% to 98.1% of primary series and 50–100% of salvage cryoablation series (Tables 24.1 and 24.2). The incidence is lowest for focal primary ablations[28] but highest for salvage total ablations.[29] In spite of a general

Table 24.1 Prostate Cryoablation Studies and Biochemical progression free survival (BPFS)

Author (Year) Reference	Type of Study	# Patients Range	Median FU Range (Months)	5-Year BPFS (%)
PRIMARY CRYOABLATION				
Alvarez Rodriguez (2015)[52]	Single series	108	100	80.4
Guo (2015)[8]	Single series all T3	75	60	48
Lian (2015)[28]	Single series	40	63	90
Liu (2015)[53]	Single series	114	24	74.6 at 24 mo
Tay (2015)[54]	Pooled data COLD	300	18.2	59.1 KM est
Ward (2014)[7]	Pooled data COLD (T3)	366	NA	51.9
Grossgold (2014)[27]	Single series	1761	320	66.9
COLD unpublished	Pooled, unpublished	4102	***	73.2
SALVAGE CRYOABLATION				
Li (2015)[55]	Single series	91	15	46.5
Chang (2015)[56]	Single series	12	33	NA
Ahmad (2013)[57]	Single series	283	23.9	44-55
Abreu (2013)[4]	Single series	25 Focal	31	54.4
		25 Total	53	86.5
Parekh (2013)[58]	Systematic review (16 studies)	18–279	9–113	18–83
Nguyen (2007)[59]	Systematic review (9 studies)	18–131	19–57	18–77
COLD unpublished	Pooled, unpublished	925	***	58.4

Table 24.2 Complications of Prostate Cryoablation: Pooled Series

Author (Year) Reference	# Patients Range	Impotence %	Pelvic/ Perineal Pain %	Retention/ Obstruction %	Tissue Slough % (Range)	Incontinence % (Range)	Fistula % (Range)	Stricture and Urethral Complications % (Range)	Others %
PRIMARY CRYOABLATION									
Alvarez Rodriguez (2015)[52]	108	98.1	11.1	1.9	5.6	5.6%	0.9%	NA	1/9% Hematuria
Guo (2015)[8]	75	NA	0	0	6.7	4	0	0	
Lian (2015)[28]	40	23.1	NA	2.5	0	2.5	0	0	
Liu (2015)[53]	114	88	NA	NA	NA	1.6	0	3.3	TURP/OIU 8.8%, scrotal edema 74.7%
Tay (2015)[54]	300	83	NA	3.3	NA	9.5	1.3	NA	
Ward (2014)[7]	366	69.6	NA	6	NA	2.6	1.1	NA	
Grossgold (2014)[27]	1761	69.6	NA	1.2	NA	1.6	0.6	NA	
COLD Unpublished	3843	**	NA	9.7	NA	6.4	1	NA	
SALVAGE CRYOABLATION									
Li (2015)[55]	91	50	NA	6.6	1.1	5.5	3.3	NA	1.1% TURP
Chang (2015)[56]	12	100	0	0	8.3	8.3	0	0	Salvage cryo after primary cryo
Ahmed (2013)[57]	283	83	4	7	NA	12	1.8	NA	LUTS 14%
Abreu (2013)[4]	25 Focal	71	NA	NA	NA	0	0	NA	
	25 Total	100	NA	NA	NA	13	4	NA	
Parekh (2013)[58]	18–279	NA	15.6 (0–39.5)	9.9 (0–21.4)	8.2 (0–52.2)	16.4 (0–91.3)	1.6 (0–11.1)	4.2 (0–44.4)	
Nguyen (2007)[59]	18–131	NA	36 (5.6–44)	NA	11 (0–55)	36 (4.3–83)	2.6 (0–11)	17 (0–28) Bladder neck contracture/ retention	
COLD Unpublished	925	***	NA	19.1	NA	28.2	2.8	NA	

***Data being analyzed for a future journal manuscript. TURP, transurethral resection of the prostate; OIU, optical internal urethrotomy; COLD, cryo online data registry; LUTS, lower urinary tract symptoms.

lack of standardization for the assessment of ED, many studies currently used standardized questionnaires like the SHIM or IIEF for assessment and follow-up after treatment. The reported incidence depends on the way ED is defined. Most studies report ED only in men who were potent prior to therapy. There are currently no studies that have looked at what constitutes a significant change in the SHIM score in order to be classified as ED. Studies have often used terms like erection sufficient for intercourse,[30] or vaginal penetration, and this is sometimes used in conjunction with the SHIM (IIEF-5) scores; one study also required potency to be classified as a score of 3 or more for Question 2 of the IIEF-5 questionnaire[28] as evidence of potency. However, for erectile function to be meaningful, patients should have the ability to get an erection (assisted or unassisted with phosphodiesterase 5 inhibitors [PDE5I]) and should be able to maintain this through sexual intercourse.

ETIOLOGY AND PATHOGENESIS. The cause of ED is multifactorial, with the precipitating factor being the cryo-injury to the neurovascular bundles. It is important to understand that many patients with prostate cancer have multiple other medical conditions that could have an impact on erectile function prior to any treatment. The Baltimore Longitudinal study has shown hypogonadal testosterone levels to increase with age and ranged from approximately 20% in men over 60 years to over 50% in men over 80 years.[31] Many patients also have hypertension requiring antihypertensive medication, and this could be complicated by the presence of diabetes and preexisting peripheral vascular disease in some patients. After cryoablation, the cause of ED is multifactorial. Studies have demonstrated a neurogenic and vasculogenic component. The direct effect of freezing the cavernous nerve has been studied in the animal model, and the authors showed decreased cavernous pressure response to nerve stimulation at 1 month but a somewhat recovered response at 3 months after the initial freezing.[32] A study found that the incidence of ED was higher when two freeze–thaw cycles were used instead of one (92% vs 77%).[30] Another study looking at the vascular component assessed cavernosal artery velocities after induction of artificial erection using prostaglandin, PGE1. The study showed the possible role of a vascular injury due to cryoablation, by demonstrating a blunted response with an overall lower peak flow velocity that also took a longer time to achieve in all of the 9/15 patients who developed ED after cryoablation.[33]

MANAGEMENT. Recovery of erectile function can be seen as late as 2–3 years after treatment. One study reported an

average recovery time of 16.4 months[34] while another reported that spontaneous recovery of erectile function occurred with time, with 47% of patients able to have sexual intercourse at 3 years, and recovery seen in one patient as late as 5 years.[35] Penile rehabilitation should be started early, and patients should be advised to be persistent. A trial of phosphodiesterase 5 inhibitors (PDE5I) alone, followed by combination therapy with PDE5I and vacuum erection device often helps. A study on penile rehabilitation after cryoablation noted improvement in results with a protocol consisting of the use of a vacuum device without constriction ring to attain an erection for 10 minutes a day and regular use of oral medication for ED.[36] Penile prosthesis should be a consideration for the motivated patient with persistent ED even after a 2–3 years of penile rehabilitation.

Perineal and/or Rectal Pain

INCIDENCE. Perineal and/or rectal pain has been described to occur in 0–11% after primary cryoablation and 4–44% after salvage cryoablation. This entity has been variably recorded and is not mentioned in many reports on primary cryoablation. However, when this complication occurs, it can be a significant problem. It was described as a cause of dissatisfaction among patients undergoing salvage cryoablation and was noted to occur in 44% of patients in one series; it was a big quality of life problem in 41% and interfered with regular activities in 38%.[30]

ETIOLOGY AND PATHOGENESIS. Many cases are probably related to prostatic and urethral or periurethral inflammation. Symptoms could mimic severe forms of prostatitis, and the pain is often described as burning; it could be associated with frequent bowel movements or rectal irritation.[37] There could be an association of this symptom with urethral slough. Higher incidence of perineal pain was noted when a urethral warming catheter was not used (70% vs 34%), and this group of patients also had more severe symptoms and were twice as likely to use narcotic pain medications.[30] Many cryosurgeons believe that excessive freezing duration in the anterior probes is a cause, so we usually limit freeze time on anterior probes to 8 minutes.

MANAGEMENT. Initial management is conservative with emphasis on symptomatic treatment. Nonsteroidal antiinflammatory drugs and acetaminophen should be tried as first line of treatment, with use of narcotic pain medications being reserved for more severe cases. Alpha blockers may be tried. Use of warm sitz baths and a donut/pillow has also been described.[30] TUR of the necrotic material can hasten recovery of pain,[37] but given the higher incidence of incontinence after transurethral resection of the prostate (TURP) following cryoablation, patients should be carefully selected based on demonstration of persistent slough or necrotic material on cystoscopy.

Urinary Retention

INCIDENCE. Urinary retention after cryoablation is seen in 0–6% after primary ablation and 0–21.4% after salvage cryoablation. From our recent COLD data, 10% of patients after primary cryoablation and 19% after salvage cryoablation had some form of retention lasting beyond the 1-week catheterization time. Incidence can change depending on the definition of retention and how soon after the cryoablation it is assessed. Urinary retention lasting more than 4 weeks was found in 29% in one older study.[37] Lower urinary tract symptoms worsen after cryoablation and will continue to improve over a period of time. The IPSS score and bother score worsen over the first 6 months but return to baseline in 12 and 18 months, respectively.[38] However, patients requiring an indwelling catheter for bladder drainage 4–6 weeks after the procedure should be considered to have a retention episode.

ETIOLOGY AND PATHOGENESIS. Urethral and prostatic inflammation and prostate swelling[39] are considered to be causative mechanisms.

MANAGEMENT. Many retention episodes are transient and require an indwelling Foley catheter for bladder drainage until the swelling resolves. After two failed voiding trials, a decision must be made regarding the next steps. Some patients can be managed with medical therapy and will void but continue to have >150 mL postvoid residual urine on a bladder sonogram. If these patients do not develop urinary tract infections or have evidence of worsening renal function, they can be closely observed for a few months. Clean intermittent self-catheterization is also an alternative, and of the patients who developed retention in the primary and salvage series of the COLD data, 16% and 18%, respectively, were managed this way; approximately 12% and 23%, respectively, underwent TURP. However, there is risk of the intermittent catheter damaging the urethra and creating a fistula, so we often limit this use to the primary treatment setting and do not advise patients to self-catheterize after salvage therapy. Suprapubic catheter placement is also an option, and some authors have used this mode of drainage after patients fail a second voiding trial.[39]

Tissue Slough

INCIDENCE. This complication has been variously reported, and many publications have omitted to mention the exact incidence. The overall incidence will be difficult to determine since all patients do not get diagnostic cystoscopies to assess for this, and often this is either a patient-reported symptom, or incidentally detected during a TURP, or cystoscopy for other reasons. The incidence also depends on the generation of machine used for cryotherapy and the use of urethral warmers. In primary ablation series, slough is described to occur in 0–6.7% cases, but in the salvage series it is reported in 1.1–55% (Table 24.2), and one series published in 1995 reported an incidence of 55%.[40] Cohen reported a 14–16% incidence in the pre-2001 era using the older machines, and this was in contrast to the 2% incidence noted after 2001.[41]

ETIOLOGY AND PATHOGENESIS. The tissue necrosis and sloughing are direct responses to the freezing of the prostate and the prostatic urethra. It is seen a few weeks after the cryoablation and can present with the patients complaining of passing tissue pieces or mucoid material or debris[37] after catheter removal. In other patients it may present with obstruction and is often the leading reason for a TURP in this setting. When done in this setting the TURP is reported to be more challenging since the normal anatomic landmarks are distorted, and this can results in over-resection.[42] The risk of incontinence, therefore is very high. The use of a urethral warmer catheter offers protection against tissue slough,[30,42] but in the study no significant relationship was

noted with the number of freeze–thaw cycles or number of probes used.[30]

MANAGEMENT. Tissue slough often presents with obstruction. Initial management should be conservative, with catheterization, with use of antibiotics and alpha blockers as indicated. A transurethral resection of the slough has a high incontinence rate. However, no studies have compared cases undergoing TURP with matched controls managed conservatively to determine the true fate and incidence of incontinence in this group managed conservatively (once the tissue debris from the prostatic urethra and/or sphincter gets passed out, and the area gets replaced with fibrosis). However, TURP may eventually be found to be necessary, and some advocate doing a limited TURP, to create a channel, and recommend that this should be done at least 3 months after the cryoablation.[42] We and most others with experience feel that TURP should be withheld until at least 12 months post treatment, especially in the salvage setting.

Less Commonly Seen Complications

Incontinence

INCIDENCE. Again, plagued by variations in definition, incontinence is reported in 1.6–9.5% of primary series and 5.5–91.3% for salvage cryoablation series (0% for focal salvage cryoablation). In a report by Bahn et al., when incontinence was defined as any leakage of urine 15.9% were considered incontinent, but when the definition was refined to include those who used any pads, the rate dropped to 4.3%.[34] The incontinence rates have also reduced in recent years with improving technology. Incontinence rates of 8.2% were noted by Cohen in the pre-1996 era using first- or second-generation machines, but this dropped to 3.2% in the 1996–2001 era and later to 0% in the post-2001 era with the use of third-generation machines.[41]

ETIOLOGY AND PATHOGENESIS. The mechanisms of incontinence after cryoablation are similar to those seen after radiation therapy or radical prostatectomy. When the prostate is ablated the change in the anatomy, damage to the external sphincter mechanism, and new-onset bladder overactivity contribute to incontinence. Compromised vascular supply to the sphincter due to microvascular damage from radiation may result in poorer healing after cryoablation and could explain the higher incontinence rates in salvage cryoablation.[42] Urge incontinence possibly from overactive bladders may be seen in up to 80% of patients having long-term incontinence.[39] Resection of the slough is also a good predictor of incontinence, and in one study all patients who were incontinent for more than 6 months had previously had a transurethral resection of the slough.[43] In another series 13 of the 15 patients who developed obstruction became incontinent either after a TURP or after spontaneous passage of slough.[42] Use of urethral warmers has been described to result in a lower rate or severity of incontinence.[30,42]

MANAGEMENT. Recovery of continence can sometimes be a slow process, and in one study, the average time to continence was 6.1 months.[34] When the predominant symptoms are suggestive of bladder overactivity, appropriate therapy with anticholinergic agents helps to decrease the incontinence. Stress urinary incontinence can be managed by sphincter strengthening exercises and physiotherapy. When such conservative measures fail, use of collagen injections or even artificial urinary sphincters has been described.[30]

Rectal Fistula

INCIDENCE. Rectal fistula rates were higher in the salvage cryoablation series. The incidence of rectal fistulas is 0–1.3% in pooled primary ablation series and 0–11.1% in the salvage cryoablation series. On review of the COLD data, rectal fistulas were noted in 1% for primary whole-gland and 2.8% for salvage whole-gland ablation.

ETIOLOGY AND PATHOGENESIS. Rectal fistulas occur when tissue freezing extends to involve the whole thickness of the rectal wall, and in the earlier series, inadequate visualization of the iceball in relation to the sagittal view of the rectal wall, due to shortcomings in imaging and ultrasound machines, may have been partly responsible for this.[41] With improvement in technology the fistula rates are now lower. Compromised tissue characteristics of irradiated tissues may be responsible for the higher fistula rates in salvage ablation series. Operator skills could also be an important factor, and an experienced surgeon has lower fistula rates. Cohen noted that most of the fistulas occur in the first 25 cases of most surgeons' series,[41] when the surgeon is still in his or her learning curve.

MANAGEMENT. Rectal fistulas often come to attention because patients complain of passing urine per rectum or a form of persistent watery diarrhea. An index of suspicion is required in order to identify cases who need to be subjected to more testing, since some rectal irritation and frequent bowel movements can be seen in the initial phase in some patients with perineal pain syndromes.[37] Some patients present with classical symptoms of the fistula and can have recurrent urinary tract infections or pneumaturia. Sectional imaging with contrast often shows loss of tissue planes at the site of communication, a retrograde urethrogram may show extravasation (Fig. 24.2), and a



Figure 24.2 Post-salvage cryotherapy urethrogram showing contrast extravasation.

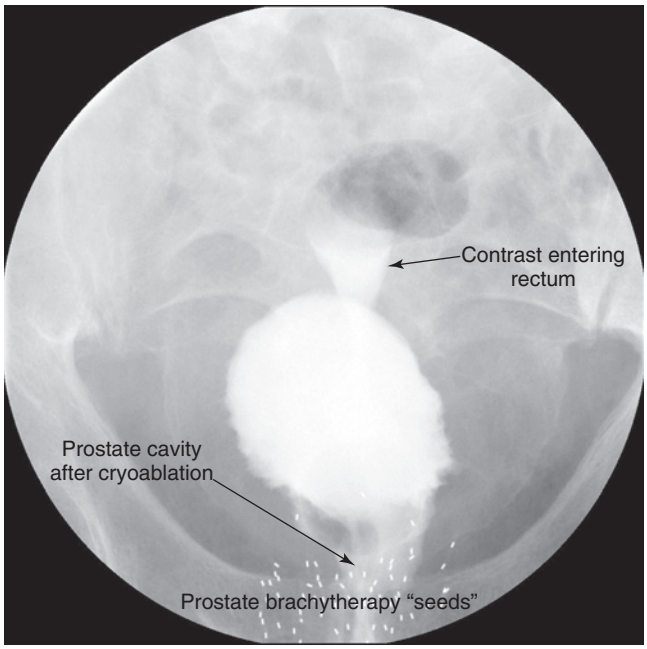


Figure 24.3 Post-salvage cryotherapy cystogram showing contrast material present in the rectum suggesting uethro-rectal fistula. (With permission from Kim IW, Herts BR, Jones JS. Rectourethral fistula after salvage cryotherapy for prostate adenocarcinoma; J Urol. 2013; Feb; 189(2):699-700.doi:10.1016/j.juro.2012.10.132.Epub 2012 Nov 10.)

conventional cystogram will show flow of contrast into the rectum (Fig. 24.3). A CT cystogram can substitute for the two investigations and has good accuracy in detecting these fistulas.

Some cases can be managed by extended catheter drainage, and spontaneous closure of the fistula with up to 3 months of catheter drainage alone has been described.[37] In our experience and also when we are consulted from other facilities for this problem, we do recommend the use of a Foley catheter for 6–12 weeks as the first-line intervention. From our center, we have also reported on a patient following salvage therapy who was managed with a suprapubic catheter and fecal diversion whose fistula closed spontaneously, and the patient underwent fecal undiversion 15 months later.[44]

Some fistulas, especially in the salvage setting are more difficult to treat and may not close spontaneously. All patients should get a urinary diversion, and a suprapubic catheter drainage is often a better option since the catheter is not traversing through the area of the fistula. In a study on rectourethral fistulas, fecal diversion was also required in 59% of patients.[45] If the fistula does not close spontaneously, some patients will go on to develop membranous urethral strictures, and this may need to addressed at the time of the repair.[46] In a study, nonirradiated patients or those with small fistulas considered to be low risk for recurrence were treated by a posterior transanosphincteric transrectal approach.[45] More complex fistulas have been managed by the use of a gracilis muscle interposition flap, or rarely even pelvic exenteration.[45] In their series, Hanna et al. noted that fecal undiversion should be offered only after careful review of the patient's progress. With this approach, 100% of their patients undergoing fecal undiversion had no complications, but 45% of patients with complex radiation-induced fistulas developed a "noncompliant rectum or anosphincteric dysfunction" and ended up having a permanent colostomy.[45] At our institution we have reported on a multidisciplinary approach involving urology and colorectal surgery. The series reported on the use of a transperineal approach with gracilis muscle interposition for the repair, including repair of membranous urethral strictures and the use of a buccal mucosa graft, supported by the corpus spongiosum and gracilis muscle flap. Notably, most of the patients in that series had fistulas related to treatments other than cryoablation.[46]

Bladder Neck Contractures/Urethral Strictures

INCIDENCE. This is seen in 3.3% of cases in the primary ablation group and 0–28% in the salvage group (Table 24.2).

ETIOLOGY AND PATHOGENESIS. Strictures and bladder neck contractures are direct results of freezing, tissue slough, infections and irritation from the catheter, and subsequent scarring and fibrosis. The use of a urethral warming device has been shown to reduce the incidence of tissue slough.[30,42]

MANAGEMENT. Urethral stricture should be managed depending on the location, length, and degree of spongiofibrosis. Bladder neck contractures can be managed by bladder neck incisions. Bulbar urethral strictures can be managed by internal urethrotomy. Membranous urethral strictures can be managed by dilatation or urethrotomy; however, the risks of incontinence are higher. Longer segment strictures may need to be treated by urethroplasty.

Rare or Anecdotal Complications

Other rarer complications have been described in an inconsistent manner in the literature. Some of these could be directly related to the procedure but others, such as a single patient death,[40] transient ischemic attack (one patient – 2%), and cerebrovascular accident (one patient – 2%),[37] may not be directly related or specific to the procedure. Acute renal failure was reported in two patients,[40] and ureteral obstruction and hydronephrosis have been described in 2%[37] to 36% in very small series, but not in any large contemporary series[40] of patients, and could be from damage to the trigone or ureteral orifices during the cryoablation. One patient in each of these series had bilateral hydronephrosis and required percutaneous nephrostomies.[37]

Penile tingling/numbness was noted in 2.6%[47] and 10%[3] and can be managed conservatively. Scrotal hematoma was noted in 5%,[37] and scrotal edema was seen in eight (7.5%) patients in one study,[39] but some degree of scrotal swelling was described to have occurred in all (100%) patients in another small series.[48] Urethrocutaneous fistula occurred in one patient and was managed by long-term suprapubic tube.[37] Hematuria was reported in four patients (3.77%) in a study.[39]

Infective complications were noted in a few patients: epididymitis was seen in three patients in one small study,[40] testicular abscess in one case,[35] one case each of prostatic abscess,[49,50] and one case each of a delayed presentation of a prostatic abscess.[39,51] Urosepsis was seen in two patients,[40] and osteitis pubis was noted in 3% of cases in one series.[50]

Conclusions

Prostate tissue ablation is increasingly being used in the primary setting. In the COLD database, 4109 patients had primary cryoablation for prostate cancer.

Impotence is very commonly seen after prostate cryoablation. The etiology is multifactorial. Impotence as a complication is, however, better accepted by the patient than incontinence. Incontinence is a troublesome complication, but its incidence is declining. Rectal fistula is one of the most dreaded complications and can be technically difficult to manage. With further improvements in imaging and in tissue ablation technology, BPFS may continue to improve, and the complication rate may continue to decrease.

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Chapter 24 Questions

1. Factors affecting degree of tissue injury using cryotherapy include which of the following?
   a. Final temperature
   b. Rate at which final temperature was achieved
   c. Number of freeze–thaw cycles
   d. All of the above
   e. None of the above

2. Using multiple (two to three) freeze–thaw cycles, the appropriate temperature to cause adequate tissue destruction is:
   a. −40°C
   b. −25°C
   c. −19°C
   d. −15°C
   e. −8°C

3. The commonest sites of cancer recurrence after cryoablation of the prostate are the following:
   a. Apex and seminal vesical (SV)
   b. Apex and midgland
   c. Base and SV
   d. Apex only
   e. Transition zone

4. Techniques that can minimize urethral slough and urethrorectal fistula following cryoablation of the prostate include which of the following?
   a. Use of TRUS to monitor the iceball
   b. Use of urethral warmer catheterization during the procedure
   c. Hydro-distention of the space between the rectum and the prostate
   d. All of the above
   e. None of the above

5. The most common complication encountered following prostate cryoablation is:
   a. Fistula
   b. Erectile dysfunction
   c. Slough
   d. Urinary retention
   e. Sepsis

6. Transurethral resection of the prostate (TURP) as a treatment option for patients who had failed conservative treatment for slough following salvage cryoablation of the prostate should be withheld at least ___ post treatment:
   a. 3 months
   b. 6 months
   c. 9 months
   d. 12 months
   e. 6 weeks

7. Management of urinary retention following salvage cryoablation of the prostate includes all of the following EXCEPT**:**
   a. Urethral catheterization
   b. Medical therapy
   c. Clean intermittent self-catheterization
   d. TURP
   e. Continuing medical management for enlarged prostate

8. Patients with urethra-rectal fistulas following cryoablation may present with:
   a. Recurrent urinary tract infection
   b. Watery diarrhea
   c. Pneumaturia
   d. All of the above
   e. None of the above

9. Mechanism of urge incontinence after cryoablation of the prostate:
   a. Compromised vascular supply to the sphincter
   b. TUR of the slough
   c. Bladder overactivity
   d. Fistula
   e. None of the above

10. Post cryoablation ED may be due to:
    a. Cryo-injury of the neurovascular bundle
    b. Hypogonadal testosterone level
    c. Preexisting medical comorbidities
    d. All of the above
    e. None of the above

Case Studies

CASE 1

A 65-year-old male was diagnosed with cT2, Gleason 4 + 3 = 7 prostatic adenocarcinoma on a standard 12-core prostate biopsy. After discussion, he opted to undergo treatment with brachytherapy. Patient's nadir PSA was achieved 2 years out of treatment at 0.6 ng/mL. He was scheduled for annual PSAs, and 4 years out of the treatment his PSA was 1.3 ng/mL. A decision was made to do the PSA every 6 months, and his PSAs over the next 2 years were 1.6, 1.9, 2.5, and 3.3 ng/mL. He was now 71 years old and a discussion 6 months back at a PSA of 2.5 included Phoenix criteria of BF and treatment options. The patient wanted to wait at that time, but now his wife wants him to strongly consider salvage cryoablation.

1. The next step in the management would be:
   a. Advise against salvage treatment and schedule for androgen deprivation therapy
   b. Schedule for a transrectal ultrasound-guided biopsy, and biopsy should include biopsy of seminal vesicles
   c. Refer for salvage external beam radiation therapy
   d. Monitor PSA every 3 months for another 2 years
   e. Repeat brachytherapy

A transrectal ultrasound-guided biopsy including biopsy of the SV revealed Gleason 3 + 4 = 7 prostate adenocarcinoma with benign SV. After discussion of treatment options, the patient elected to undergo whole-gland salvage cryotherapy.

He presented with progressive irritative voiding symptoms 4 months after undergoing salvage cryotherapy.

2. Which of the following is the least likely cause of symptoms?
   a. Infectious etiology like cystitis or prostatic abscess
   b. Anatomic abnormality like urethral stricture or bladder neck contracture
   c. Tissue slough
   d. Rectoprostatic fistula
   e. Urinary tract infection

3. Which of the following is not an appropriate next step?
   a. Urine culture followed by antibiotics
   b. Preparation for a cystoscopy
   c. Low-dose chemoprophylaxis and return to clinic in 6 months
   d. Consider for imaging for bladder or prostatic urethral stones and/or fistula
   e. CT cystogram

CASE 2

A 73-year-old man with a PSA of 6.2 ng/mL was found to have a Gleason score 3 + 4 = 7 prostate cancer and opted to undergo cryoablation. His Foley catheter was removed 1 week after the procedure, but later that evening the patient returned to the ER and was catheterized for a returned volume of 800 mL. He was seen in the office a few days later and started on tamsulosin. One week later he underwent a trial of voiding and was able to void. Another week later he called with complaints that his stream had been weak all along, and now was having frequency and some urgency and nocturia, along with some perineal pain/discomfort and was also passing some tissue pieces in the urine intermittently.

1. At this point in time the most likely primary problem is:
   a. Urinary tract infection
   b. Tissue slough
   c. Urethral stricture
   d. Prostatic abscess
   e. Bladder stone

A bladder scan is done, and patient is in retention with over 700 mL in the bladder. A Foley catheter is placed, and the patient returns after another week and fails yet another trial of voiding.

2. Which of the following is not considered a good option at this point in time?
   a. Reinsert Foley catheter
   b. Suprapubic tube placement
   c. Clean intermittent self-catheterization
   d. TURP
   e. Cystolithotripsy

3. A suprapubic catheter is placed, and a few months later the patient is taken up for a TURP. What procedure-specific complication must the patient be warned about?
   a. Urinary incontinence
   b. Recurrent urinary tract infections
   c. Recurrent bladder stones
   d. Erectile dysfunction
   e. Regrowth of adenoma

Answers

1. **d.** Factors affecting the degree of tissue injury during cryoablation of the prostate include the final temperature and the rate at which it is achieved, as well as the number of freeze–thaw cycles used.
2. **c.** A temperature of −40°C was shown to cause adequate cell destruction. However, using a newer technique during cryoablation either through multiple (double or even triple) freeze thaw cycles, that keep cells at subzero temperatures for a longer time or by ensuring the right combination of cooling rate (25°C/min) plus end point temperature, cell death can be achieved at a higher temperature of −19°C.
3. **a.** Most of the local recurrence after cryoablation of the prostate occurs in the prostate apex and the SV as they are usually undertreated.
4. **d.** The hydro-distention technique using saline injection to separate the rectal wall from the prostate during cryosurgery has markedly decreased the incidence of urethra rectal fistula following the operation. Moreover, the use of TRUS to monitor the iceball and urethral warming device decreases the effects on the urethra and minimize urethral slough.
5. **b.** ED is the most commonly encountered complication following cryoablation of the prostate and is due to the effect of freezing that causes damage to the neurovascular bundles. However, other medical conditions may contribute to the development of ED prior to any treatment.
6. **d.** Following salvage cryoablation of the prostate, the incidence of incontinence and urinary retention rates increase. Spontaneous resolution occurs in half of the patients within 1 year, especially with the use of urethral warmer. Most of the authors recommended withholding incontinence treatment and TURP until at least 12 months post salvage cryotherapy.
7. **c.** Self-intermittent catheterization may damage the urethra and create fistula, especially in the salvage setting, and so should be avoided.
8. **d.** Rectal fistulas following cryoablation of the prostate may present with passing urine per rectum or a form of persistent watery diarrhea. Some patients present with classical symptoms of the fistula and can have recurrent urinary tract infections or pneumaturia.
9. **c.** Overactive bladder presents with urge incontinence following cryoablation of the prostate. Urge incontinence from overactive bladders may be seen in the majority of patients having long-term incontinence.
10. **d.** ED is multifactorial; the precipitating factor is the cryo-injury to the neurovascular bundles. Multiple other medical conditions including preexisting DM that could have an impact on erectile function prior to

any treatment. The hypogonadal testosterone levels also increase with age, which may contribute to ED following cryoablation of the prostate.

CASE 1

1. **b.** A biopsy confirmation of recurrence is necessary before planning salvage cryoablation. The biopsy should exclude an SV recurrence, as these case are not suitable for salvage cryoablation.
2. **c.** Tissue slough is seen earlier in the course after cryoablation and more often presents with retention or difficulty in voiding.
3. **c.** This could potentially delay the diagnosis. A physical examination was done followed by a cystoscopic evaluation, and this revealed findings suggestive of a rectourethral fistula. A cystogram showed active communication between the bladder and rectum. The patient underwent bowel diversion with loop sigmoid colostomy and urinary diversion with suprapubic tube placement for the rectourethral fistula. Contrast enema 8 months after diversion showed resolution of the fistula, the patient was able to void normally, and the suprapubic tube was removed. Repeat barium enema revealed a small pocket of contrast at the area of injury but no fistula. The patient underwent reversal of both diversions 15 months after the original presentation and is doing well.

CASE 2

1. **b.** Tissue slough can present this way.
2. **d.** Most clinicians would not consider a TURP until at least 3 months out of the procedure.
3. **a.** Patients undergoing TURP after cryoablation are at risk for urinary incontinence and should be warned about this.

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SECTION V

Complications of Endourologic Procedures

25 Complications of Transurethral Resection of Bladder Tumors

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CHAPTER OUTLINE

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Irrigating Solutions
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Resection
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Restaging Transurethral Resection of Bladder Tumors
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Conclusions
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KEY POINTS

1. Equipment should be inspected by the surgeon and nursing team prior to its use to ensure proper selection and good working order.
2. Depending on the type of diathermy selected, all irrigant solutions are suitable for use with transurethral resection of bladder tumors (TURBT), each with its unique advantages and limitations.
3. A thorough preoperative evaluation, including anesthesia and subspecialty referral when indicated, will optimize patient health and lessen the likelihood of complication.
4. Documentation of a negative urine culture is recommended prior to TURBT.
5. Careful patient positioning and padding can prevent severe lower extremity nerve injury and lasting disability.
6. Office-based, flexible cystoscopy can assist in planning a successful procedure by providing a resection map. Tumor located on the anterior wall, on the lateral walls, at the dome, in a diverticulum, or involving the ureteral orifice may require special equipment or additional anesthetic considerations.
7. Bleeding is the most common complication associated with TURBT. Depending on its severity, it can be managed with continuous bladder irrigation through a 3-way catheter (using saline, alum, or Amicar), repeat endoscopic fulguration, open surgery, or arterial embolization.
8. Perforation increases the risk of numerous other complications including bleeding, infection, TUR syndrome, and possible disease spread. Careful planning, appropriate equipment

selection, diligent attention to operative technique, and effective communication between the surgical, anesthesia, and nursing teams lessen the likelihood of perforation occurring.

9. TUR syndrome can be a lethal complication. Prompt identification and management are critical. Transferring the patient to a monitored setting (ICU) is often appropriate.
10. Resident involvement in TURBT can increase operative time and readmission rates but does not seem to increase overall complication or reoperation rates.
11. Post-TURBT intravesical chemotherapy is contraindicated with known bladder perforation. Intravesical Bacillus Calmette-Guerin (BCG) is absolutely contraindicated in the immediate postoperative setting.
12. Staff responsible for administering, monitoring, and disposing of intravesical chemotherapeutics must understand how to maintain a safe working environment for themselves and their patients.

Introduction

Transurethral resection is not only the initial treatment for bladder tumors but also provides tissue for the pathologic evaluation of tumor stage and grade, making this procedure both therapeutic and diagnostic. This chapter will discuss strategies to reduce perioperative complications and maximize patient outcomes. Since transurethral resection of bladder tumors (TURBT) shares many techniques and hazards with transurethral resection of the prostate (TURP), we will refer to the excellent discussion in Chapter 26 at several points.

General Considerations

The vast majority of patients who undergo TURBT have already had office-based cystoscopy. This gives the surgeon an opportunity to not only note the location, number, and appearance of bladder lesions, but to also look for possible barriers to successful resection such as problems with mobility (hip/knee range of motion) and urethral/bladder access (phimosis, stenosis, stricture). These findings should be relayed to the operating room scheduler in a timely fashion to ensure that the appropriate personnel, equipment, and operating room time are available.

Surgical Instrumentation

The equipment used for TURBT is nearly identical to that for TURP. A full list of the mandatory and optional equipment is provided in Table 25.1. A dedicated cystoscopy suite is an excellent way to centralize all the necessary equipment and ensure that the operating table is both maneuverable and compatible with lithotomy stirrups and C-arm fluoroscopy. A variety of urethral catheters should also be on hand for postprocedure bladder drainage including conventional Foley and coude catheters, as well as three-way catheters for continuous bladder irrigation (CBI or Murphy drip).

All instrumentation should be maintained regularly so that worn or ill-fitting parts can be serviced. The nursing staff and surgeon should inspect the set-up prior to starting the case to confirm that the necessary equipment has been picked and that any contingency items are immediately available. This step may seem to add time to the procedure but it is far riskier to proceed only to find out that an urgently needed item is broken or was mislabeled during processing and is therefore not on hand. It is the surgeon's ultimate responsibility to confirm the good working order of his/her equipment, and a preprocedure check should become as much of a habit as the "right patient/right site" preoperative verification for patient safety.

Table 25.1 Equipment Necessary for Transurethral Resection of Bladder Tumor

Equipment Required	Optional Equipment
Endoscopic sheaths (20F, 24F, 28F, deflecting)	Urethral sounds
Resecting loops	Evacuators (Toomey, Ellik, Creevy)
Roller ball	Urethral access catheter
Right-angle electrodes	Contrast
Marberger cold-cup biopsy forceps	Fluoroscopy
Generator with grounding pad	
Lens (30-degree and 70-degree)	
Camera and light source	
Irrigation tubing and irrigant	
Water-soluble lubricant	
Specimen cups	

Irrigating Solutions

Copious amounts of the surgeon's irrigant of choice must be readily available. An experienced nursing team, the members of which understand that any loss of visibility not only prolongs the procedure but also increases the likelihood of an adverse event, is invaluable.

Since the bladder does not readily absorb its contents, the use of sterile water is safe, unlikely to result in hemolysis or hyponatremia (transurethral resection (TUR) syndrome), and yields outstanding endoscopic visualization. In a comparison of glycine and sterile water use for the resection of superficial bladder tumors, the two solutions were found to be equally effective and sterile water was less expensive.[1] However, for long resections of large, hypervascular tumors, changing to an iso-osmotic fluid should be considered. Bipolar resectoscopes allow for the use of normal saline as the irrigant, lessening the risk of hyponatremia.[2]

Sorbitol, mannitol, and glycine are all suitable options but each has a metabolic profile that must be considered (see Chapter 26 for detailed discussion). Sorbitol is metabolized to glucose and can result in hyperglycemia, making it

a less desirable choice for diabetic patients. Mannitol, an osmotic diuretic, can cause intravascular fluid shifts if absorbed further, exacerbating hyponatremia. Lastly, ammonia is a metabolic breakdown product of glycine, which can increase the risk of hyperammonemia and resultant encephalopathy in patients with poor hepatic function. Bladder perforation, which will be addressed later in this chapter, is an absolute contraindication to continued resection regardless of the irrigant being used.

Patient Preparation

The National Surgical Quality Improvement Program (NSQIP) has laid an important foundation for the development of surgical risk–reduction strategies. Recently, Matulewicz and colleagues used the NSQIP data from 2006 to 2012 to examine postoperative complications stratified by TURBT duration. They adjusted for patient age, tumor size, comorbidities, and American Society of Anesthesiologists (ASA) classification. They found that the incidence of complications increased with operative duration. For cases longer than 90 minutes in duration the complication rate was 11.3%. Complications included mortality, myocardial infarction, sepsis/septic shock, venous thromboembolism (VTE), and reintubation/respiratory failure.[3] Hollenbeck and colleagues also used NSQIP data to specifically identify risk factors for adverse outcomes following TURBT.[4] They found that the presence of disseminated bladder cancer, weight loss (≥10%), low serum albumin, elevated serum creatinine, dependent functional status, and emergent case status were significant preoperative predictors of adverse outcomes. Perioperative predictors included postoperative hyponatremia and the need for intraoperative blood transfusion. In another study, McLaughlin and colleagues reported on a pilot study that examined the risk factors associated with 30-day morbidity in a non–Veterans Affairs urology setting (including open, laparoscopic, and endoscopic procedures).[5] Not surprisingly, the authors found that patients who have comorbidities such as heart disease (hypertension, angioplasty, myocardial infarction, congestive heart failure); lung disease (dyspnea, asthma, chronic obstructive pulmonary disease); diabetes (with or without end organ damage); cancer (second nonmetastatic solid tumor initially treated within 5 years, prior chemotherapy); laboratory abnormalities (anemia, elevated blood urea nitrogen [BUN]); and poor operative risk scores (Charlson comorbidity index score, American Society of Anesthesiologists' physical status class 3–5) or who underwent longer procedures or required intraoperative blood transfusion were much more likely to suffer a complication within the first 30 days of surgery. Due to the epidemiology of bladder cancer, patients undergoing TURBT are likely to have one, if not several, of the risk factors identified in the two studies above.

PREOPERATIVE EVALUATION

Maximizing patient health status preoperatively is always beneficial. Attention to cardiopulmonary status, renal function, and identifying any issues with coagulation are of specific concern. Following a detailed history and physical examination, correspondence with a patient's primary care provider and consultation with an anesthesiologist can help identify areas for optimization before TURBT. Preoperative EKG, chest x-ray, and laboratories (complete blood count [CBC], prothrombin time [PT]/partial thromboplastin time [PTT]/ international normalized ratio [INR], chemistry-14 or comprehensive metabolic panel) allow the patient to be referred for evaluation by a specialist if needed.[6] Blood bank cross matching may need to be considered in select cases.

MEDICATION COUNSELING

Patients will need to be counseled about which medications (prescription, over-the-counter, and supplements) they should discontinue, how long they must abstain preoperatively, and when it is safe to resume their usual regimen. Special attention must be paid to patients with diabetes or hypertension to ensure euglycemia and normotension in the perioperative period.

The preoperative planning for patients taking anticoagulants (warfarin, dabigatran, apixaban, edoxaban, heparin, etc.) and antiplatelet agents (clopidogrel, prasugrel, ticagrelor, ticlopidine, cilostazol, aspirin, NSAIDs, etc.) requires careful coordination with the prescribing provider. Some patients, such as those with artificial heart valves, cardiac stents, or hypercoaguable states, may need to be admitted and heparinized to mitigate the risk of clot formation (see Chapter 4). Postoperatively, determining when patients should resume their usual anticoagulation/antiplatelet regimen will require weighing the risks of bleeding against those of thrombus formation.

URINE CULTURE AND ANTIBIOTIC PROPHYLAXIS

A documented negative urine culture is recommended prior to transurethral surgery. Any suspicion of infection should result in immediate culture, appropriate antibiotic therapy, and rescheduling the procedure until the urine has been documented to be sterile on repeat culture. Preoperative antibiotic prophylaxis, usually with a cephalosporin, sulfamethoxazole-trimethoprim, or a fluoroquinolone, is recommended.[9] Of note, prescribers should be aware of the July 2016 black box warning issued by the US FDA regarding fluoroquinolone antibiotics. This warning did not address the use of fluoroquinolones as presurgical prophylaxis, but the potential risk from this class of drugs should be weighed when selecting a preoperative antibiotic. Second-line options include aminoglycosides, ampicillin, or a cephalosporin. The antibiotic choice should be altered in the case of an allergy or certain other aspects of the patient's medical history, including documented UTI with resistance to that agent, artificial heart valve, joint replacement, etc.[9] Antibiotic prophylaxis is recommended for 24 hours unless the patient has a positive urine culture indicating therapy should be extended.[9]

Anesthesia and Positioning

ANESTHESIA

Selecting the appropriate anesthetic regimen is a collaborative process involving the patient, anesthesiologist, and

surgeon. For TURBT, the choice is between regional (spinal or epidural) and general (laryngeal mask or endotracheal tube) anesthesia. If a regional approach is chosen, the anesthesiologist should be prepared to deepen the patient's sedation, and even intubate if needed, to prevent the patient from coughing or bucking during the procedure. Sudden movement can result in significant complications, such as imprecise resection, hemorrhage, and bladder perforation. If the tumor is located laterally in the bladder, general anesthesia is appropriate because a paralytic can be given to eliminate leg adduction should current from the resecting loop stimulate the underlying obturator nerve.[10–12] Similarly, injection of 30 mL of local anesthetic as an obturator block can significantly decrease nerve sensitivity and adductor strength.[13–22]

PATIENT POSITIONING

Proper positioning is a fundamental aspect of any procedure performed in the lithotomy position. The surgeon, anesthesiologist, and nursing team should concur that all bony prominences are adequately padded and that the legs are secured within the stirrups to ensure minimal risk of nerve injury (Table 25.2). The patient should be appropriately covered to prevent hypothermia and its sequelae (impaired drug metabolism, prolonged emergence from anesthesia, coagulopathy, postoperative discomfort)[23] as a significant amount of body heat can be lost ambiently and through the irrigating fluid used intraoperatively. Warming the irrigant or using a warming blanket/forced air device can be beneficial in longer cases. Since patients with malignancy have an increased risk of venous thromboembolism, sequential compression devices (SCDs) are applied to the lower extremities for all cases that may last more than 1 hour, although many surgeons choose to use them for even shorter cases.[24] It is critical to have the SCDs in place and functioning prior to induction, when the risk of DVT increases.

Surgical Approach

RESECTION

As mentioned earlier, the information gathered during office-based flexible cystoscopy can aid in the planning of TURBT. Adjustments in equipment selection and technique may need to be made based on the size, location, and number of tumors seen (Figs. 25.1 and 25.2 and Table 25.3).

Table 25.2 Nerve Injury due to Lithotomy Positioning[110]

Nerve Injured	Physical Deficit	Caused by
Sciatic	Inability to flex knee	Excessive external hip rotation
Femoral	Inability to flex hip or extend knee	Excessive external hip rotation
Common peroneal	Foot drop (loss of dorsiflexion)	Compression of lateral knee at proximal fibula

(From Gonzalgo M. Bladder cancer: Superficial. In: Parsons J, Wright E, eds. The Brady Urology Manual. London: Informa Healthcare; 2006.)

DIFFUSE CARCINOMA IN SITU

The initial standard therapy for *carcinoma in situ* (CIS) is intravesical therapy with attenuated Mycobacterium bovis Bacillus Calmette-Guérin (BCG).[25] If CIS is believed to involve extensive segments of the bladder, representative biopsies with hemostatic fulguration are preferable to

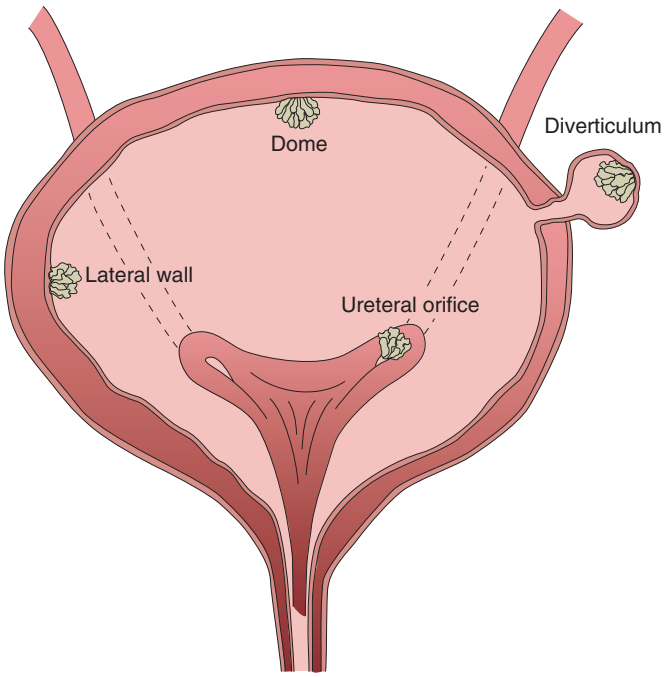


Figure 25.1 Office-based flexible cystoscopy allows the surgeon to map out the location of tumors and plan an appropriate resection. High-risk or challenging resection areas include the dome (perforation), lateral walls (obturator reflex), and ureteral orifice (obstruction).

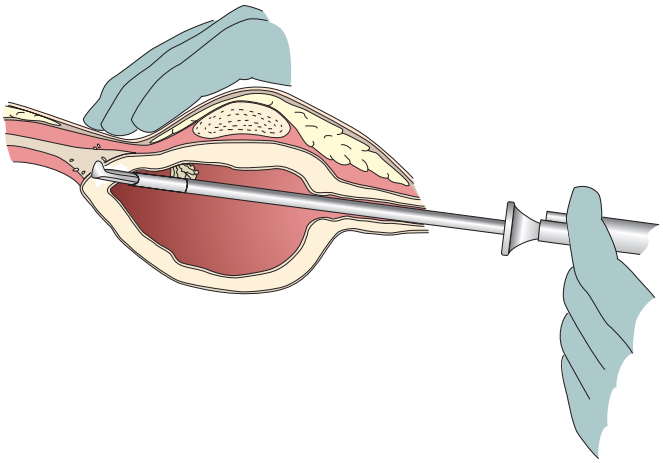


Figure 25.2 Resecting a tumor on the anterior wall of the bladder can be facilitated by using one's nonoperative hand to apply downward suprapubic pressure (anterior to posterior) to bring the area of interest into view. Care must be taken to control the end of the resectoscope at all times; the dome of the bladder can be perforated resulting in potential bowel injury.

Table 25.3 Challenging Bladder Tumor Locations

Location	Unique Risks	Preventative Measures
Ureteral orifice	Ureteral stricture	Resect with cutting current, use only pinpoint cautery
Bladder dome	Poor visualization Risk of perforation	Use continuous flow sheath Do not overdistend the bladder
Lateral wall	Obturator reflex	Do not overdistend bladder Decrease cut/coagulation current settings Obturator nerve block or general anesthesia with paralysis
Diverticulum	Risk of perforation	Do not resect too deeply

cauterizing large swaths of the bladder mucosa. Extensive use of electocautery over a large surface area can result in bladder contracture.[26] Recently, hexaminolevulinate (HAL) has begun to be used in combination with blue-light cystoscopy. This was approved for use in the United States in 2010, and since then experts recommend considering blue-light cystoscopy for assessment of CIS in patients with positive urine cytology, but negative white-light cystoscopy findings.[27]

TUMOR INVOLVING THE URETERAL ORIFICE

A tumor near or involving the ureteral orifice poses the challenge of obtaining complete resection and adequate hemostasis while preserving the caliber of the intramural ureter. Resecting with a purely cutting current and the judicious use of pinpoint cautery (with a right-angle cautery electrode) at the lowest effective setting for hemostasis make ureteral stricture unlikely.[28–32] If postoperative flank pain develops, a renal ultrasound can be performed to evaluate for hydroureteronephrosis. If present, a percutaneous nephrostomy tube can be placed. Tumor location at the ureteral orifice should not deter appropriate endoscopic management.

Reflux of urine into the upper tracts, which may occur with ureteral stenting (either anterograde or retrograde) or via vesicoureteral reflux following resection of the ureteral orifice, has been shown to increase the risk of seeding and tumor occurrence in the ureter and renal pelvis in some retrospective studies.[33–36] Conversely, Solsona and colleagues found no significant difference in upper tract recurrence patterns when refluxing and nonrefluxing patients were studied post-TURBT.[37] Regardless, close follow-up and monitoring for bladder as well as upper tract recurrence are advisable. Patients who symptomatically reflux after TURBT have been successfully managed with the endoscopic injection of bulking agents.[38] Surgical reimplantation of the refluxing ureter is also possible.

TUMOR ON THE ANTERIOR SURFACE

Resecting a lesion on the anterior surface of the bladder can be facilitated by using one's nonoperative hand to apply downward suprapubic pressure (compressing the anterior wall toward the posterior wall) on a bladder only partially filled with irrigant to allow better visualization of the tumor.[10,28]

TUMOR AT THE DOME

Resection at the bladder dome is challenging because of its anatomic relationships. It is the furthest point from the trigone, making visualization difficult; the more irrigant used to clear away blood the further the point of interest travels from the resectoscope. A continuous flow resectoscope sheath can be especially useful in this situation. Additionally, bowel can overlie the dome and be injured by transmural current from aggressive electrocautery. Lastly, the elderly in general, and postmenopausal women in particular, have significantly thinner bladder walls, making perforation an even greater concern. Taking care not to overdistend the bladder and paying meticulous attention to resection technique and depth are important when working at the dome.

TUMOR AT THE LATERAL WALL

In addition to the anesthetic options discussed above, there are several techniques the surgeon can employ to lessen the likelihood of a complication stemming from the inadvertent stimulation of the obturator nerve during resection of a laterally located tumor. Preventing overdistention, decreasing the cutting/coagulation current settings, and the use of intermittent cautery can lessen the incidence of adductor contraction.[10,14,39] The endoscopic injection of local anesthetic into the tumor base can also deliver an obturator nerve block if a percutaneous attempt was not made preoperatively.[39] Lastly, use of a bipolar resecting system restricts the flow of current to between the two electrodes of the resecting loop thus decreasing stimulation of the obturator nerve.[40,41]

TUMOR IN BLADDER DIVERTICULA

It is critical to remember the anatomic differences of bladder diverticula; by definition, they lack the muscularis propria layer making them thinner and much easier to perforate. This aspect can also make the pathologic staging of lesions within diverticula more difficult. Golijanin and colleagues from Memorial-Sloan Kettering Cancer Center have put forth post-TURBT staging and treatment recommendations based on their experience.[42] They suggest that conservative treatment is appropriate when the tumor is confined to the diverticula, it can be resected in its endoscopic entirety, and the patient is agreeable to close follow-up. For large or high-grade tumors, transurethral biopsy followed by partial cystectomy may be more prudent than attempting complete transurethral resection.[43]

RESTAGING TRANSURETHRAL RESECTION OF BLADDER TUMORS

American Urological Association (AUA) guidelines and European Association of Urology (EAU) guidelines recommend repeat resection for all patients with lamina propria invasion without muscularis propria present in the specimen.[44,45] In addition, EAU guidelines recommend restaging

in all T1 tumors as well as all high-grade Ta tumors.[44] According to AUA guidelines, repeat resection is considered for patients with high-grade Ta bladder cancer and T1 tumors with muscularis propria in the specimen.[45]

Restaging TURBT is typically performed 6–8 weeks following initial resection. Richstetter and colleagues found that residual tumor was found in 38% of restaging TURBT specimens.[46] The risks of restaging TURBT are similar to the risks of initial TURBT and include anesthetic risk, bleeding, perforation, potential delay of definitive therapy, and increased difficulty with future therapies such as cystectomy.[47]

"RADICAL" TRANSURETHRAL RESECTION OF BLADDER TUMORS FOR MUSCLE INVASIVE BLADDER CANCER

Bladder preservation surgery for select patients with bladder cancer is an option. This can be achieved with combined chemoradiation. The patients undergoing this approach must be willing to undergo lifelong surveillance cystoscopy, multiple TURBTs, and possible intravesical therapy. Recurrent T1 or T2 disease with restaging indicates that patients should not undergo bladder preservation. Candidates for bladder preservation are limited to those who are not surgical candidates due to comorbidities or those who refuse cystectomy.[48]

MONOPOLAR VERSUS BIPOLAR ELECTROCAUTERY

Both bipolar and monopolar electrocautery can be used for transurethral resection of bladder tumors. A recent study retroactively compared monopolar versus bipolar TURBT. The study examined perioperative complications in monopolar versus bipolar TURBT. They found that bipolar TURBT was associated with a lower incidence of bladder injury, with slightly shorter postoperative length of hospitalization and lower costs.[49] In contrast, Venkatramani and colleagues found that bipolar transurethral resection was not superior to monopolar with regard to obturator reflex, bladder perforation, or hemostasis.[50] However, other authors have reached the opposite conclusion.[40,41]

REDUCING CAUTERY ARTIFACT

While typically not considered a complication, excessive cautery artifact is both counterproductive and preventable. Cold-cup biopsies can be obtained prior to resection or fulguration. Adjustment of the resectoscope's power to the lowest effective setting combined with the preferential use of pure cutting current also aids the pathologist in his or her grading/staging evaluation.[26] Alternatively, obtaining hemostasis via fulguration after adequate specimens have been obtained helps to preserve the microscopic appearance of the samples. There are differing opinions on whether use of bipolar energy decreases the degree of cautery artifact when compared to monopolar resection.[50,51]

USE OF LASERS

Several different types of lasers have been used to treat bladder cancer, including neodymium-YAG, argon, potassium titanyl phosphate (KTP), and holmium-YAG.[52–55] The neodymium-YAG was found to be equally as effective as conventional TURBT in a prospective randomized trial, making it the laser of choice for some surgeons. Since laser energy vaporizes or coagulates the tissue it contacts, cold-cup biopsies should be performed prior to using the laser to resect a suspicious lesion. Likewise, determining tumor depth or muscular invasion is not readily possible with this type of resection, making patients with papillary, low-grade tumors the most appropriate population for this technology.[56]

A recent meta-analysis reviewed seven randomized control trials to evaluate transurethral laser therapy for nonmuscle invasive bladder cancer. The study demonstrated decreased obturator reflex, decreased bladder perforation, and decreased length of stay for laser therapy compared to TURBT.[57] Yang et al. also performed a retrospective analysis of laser vaporization versus TURBT and demonstrated that phosphate laser vaporization for nonmuscle invasive bladder cancer resulted in fewer perioperative complications and lower recurrence.[58] The most significant complication of laser use is the transmural passage of energy resulting in the perforation of an adjacent structure, such as an overlying loop of bowel, but this risk is low.[1,59,60]

Complications of Transurethral Resection of Bladder Tumors

Nearly all patients with bladder cancer will undergo TURBT at least once, making it the most common surgical therapy for this disease.[61] In studies of postoperative resource use, patients who have had TURBT often need additional medical services and readmission at higher rates than similar patients receiving other ambulatory procedures.[62,63] It is incumbent on all urologists to review their practice patterns in order to lessen the complications associated with this procedure.

OVERALL MORBIDITY AND MORTALITY

While TURBT is typically a safe and well-tolerated procedure, urologists must be mindful of the morbidity (5.1%[39] to 43.3%[64]) and mortality rates (0.8%[65] to 1.3%[64]) reported in the literature.

MECHANICAL DIFFICULTIES

The list of possible mechanical failures or difficulties that can occur during TURBT is myriad. The surest way to minimize this frustrating event is by carefully examining the selected equipment prior to initiating the procedure. Clear, timely communication between the surgeon and operative team (anesthesia and nursing) regarding unexpected findings, the need for replacement, additional or specialized equipment, or any adjustments in the estimated operative time can help increase efficiency and patient safety.

PROBLEMS OF INSTRUMENT INTRODUCTION

Barriers to effective transurethral surgery such as phimosis, meatal stenosis, or urethral stricture should be noted during

flexible office cystoscopy. If an operative intervention is needed to correct one of these conditions prior to TURBT, the surgical consent form should be amended and the necessary additional equipment selected. The techniques for circumcision, meatal dilation/meatoplasty, and optical internal urethrotomy (OIU) are described in greater detail in Chapter 26 and other surgical texts.[66] If for some reason office cystoscopy has not been performed prior to TURBT, the surgical consent should reflect the possible need for additional interventions.

POSTOPERATIVE BLEEDING

Postoperative bleeding is the most frequently reported complication of TURBT with rates ranging from 2% to 13%.[39,64,67] Intraoperative or postoperative bleeding is typically associated with large tumors and extensive or complex resections.[39,68] Careful examination of all resected areas under little to moderate distention is important so as not to miss small vessels temporarily tamponaded by a distended bladder. Unfortunately, coughing or bucking by the patient on emergence from general anesthesia can cause a significant increase in blood pressure resulting in a loss of hemostasis. Prompt management (removal of stimulus, sedation, or antihypertensives) can decrease systemic blood pressure and allow clot formation. If symptomatic hypotension or tachycardia ensues that does not respond to a fluid bolus, transfusion of packed red blood cells (PRBC), laboratory work (CBC, PT/PTT/INR, basic metabolic panel), and resuscitative measures are indicated.

Insertion of a transurethral catheter is common post-TURBT. Choosing a three-way catheter (20–24F) enables the use of CBI in the recovery room, if needed. It is critical to include orders for scheduled and PRN manual irrigation with 60–120 mL of normal saline via a 60-mL catheter-tipped syringe to remove any sediment or small blood clots that may have formed. The relatively small lumens of the inflow and outflow tracts in a three-way catheter, even in a large 24F catheter, can become clotted off easily and can lead to iatrogenic bladder perforation if the bladder continues to fill but is unable to drain. Continuous bladder irrigation should only be gravity fed; it must never be attached to an IV pump. Additionally, CBI is contraindicated with a bladder perforation. Titrating the flow for pink urine is usually adequate to limit clot formation. All nursing staff caring for a patient on CBI must be oriented to the apparatus and must strictly monitor and record the amount of irrigant instilled and returned and understand how to calculate urine output (total output − irrigant instilled = urine output).

If the degree of postoperative hemorrhage is significant and results in physiologic changes (hypotension, tachycardia) despite fluid resuscitation or repeated transfusions, returning the patient to the operating room for clot evacuation and fulguration is advisable. If hemorrhage is still uncontrollable, conversion to open cystectomy or embolization of the internal iliac artery by interventional radiology/vascular surgery may be necessary.[69–72] Selective and superselective embolization techniques have since been developed in the attempt to minimize potential morbidity.[73–75] In summary, the surgeon should first consider taking the patient back to the operating room for hemostasis. After determining that this is not advisable, other measures may be utilized.

BLEEDING DUE TO UNRESECTABLE DISEASE, RADIATION, OR CHEMOTHERAPY

Significant hematuria in an oncology patient, regardless of cause, will often result in urologic consultation. The urologist should also be familiar with intravesical agents that are commonly used to manage hemorrhagic cystitis due to unresectable tumor, prior external beam radiation, or chemotherapy treatment. Some of these patients may be poor operative candidates, making intravesical treatments valuable temporizing measures.

Use of a 1% alum solution (50 g of aluminum ammonium sulfate or aluminum potassium sulfate dissolved in 5 L sterile water)[76] functions as an astringent by causing protein precipitation and vasoconstriction.[77] This can be delivered in the same manner as saline CBI. The alum will cause a precipitate to form, so manual irrigation via a piston syringe (60-mL catheter-tipped syringe) will be required to ensure adequate outflow. Aluminum absorption is possible, especially if large portions of the bladder have been resected. Signs of aluminum toxicity, which is more likely in patients with renal dysfunction and can be fatal, include lethargy, confusion, seizures, and metabolic acidosis.[76,78] Alum irrigation should be stopped immediately and bloodwork (serum aluminum level) sent.

Chapter 26 discusses the use of intravenous and oral aminocaproic acid (Amicar; an inhibitor of plasminogen activators, which interferes with fibrinolysis) in the management of post-TURP bleeding. The same regimen can be employed post-TURBT or mixed as a solution for use with CBI. It is important to rule out disseminated intravascular coagulation (DIC) as the source of bleeding by evaluating the patient's platelet count and fibrinogen level prior to initiating aminocaproic acid therapy.[79]

Instillation of intravesical formalin has been used to manage refractory hematuria due to advanced bladder cancer and hemorrhagic cystitis due to external beam radiation or cyclophosphamide chemotherapy.[80] Formalin causes protein denaturation and precipitation in the bladder mucosa resulting in blood vessel occlusion.[81] This treatment should not be considered first-line therapy, and it is not advisable to use it in the immediate postoperative period because absorption is possible. Pretreatment cystography is recommended to evaluate for reflux and bladder integrity.[76] Complications, both local and systemic, include bladder contracture, urinary incontinence, vesicoureteral reflux, ureteral stricture and obstruction, acute tubular necrosis, vesicovaginal or enterovesical fistula formation, myocardial injury, and bladder rupture.[82–90] Bladder fibrosis with reduced capacity and resultant urinary frequency is a common side effect.[76]

BLADDER PERFORATION

Bladder perforation is one of the most significant complications associated with TURBT. It can result in numerous sequelae including hemorrhage, TUR syndrome, infection, the need for urgent open surgery, tumor spillage, peritonitis, and death.[64,91] Mindful assessment of inflow and outflow

irrigant volumes during extensive resection may prompt the recognition of serious occult bladder perforations. Bladder perforation typically occurs extraperitoneally, which can usually be managed with drainage via a large caliber urethral catheter (20–24F) for 7–14 days with a cystogram prior to removal. For large intraperitoneal perforations, surgical repair should be performed. This should be performed especially if tumor resection is incomplete and the risk of tumor spillage is high. Drain placement by interventional radiology may be required if there is a large amount of extravasated irrigation fluid.

The incidence of post-TURBT perforation may be underestimated. In a prospective study, Balbay and colleagues performed cystography after TURBT in a series of 36 patients with suspected bladder cancer.[92] They found contrast extravasation in 58.3% of their patients, compared to other series reporting perforation in only 1–5% of cases.[39,93,94] The significance of subclinical perforations detected by cystography is unclear. In an editorial accompanying the Balbay report, Soloway raises concerns about the oncologic efficacy of "radical TUR," meaning that resecting to the point of perforation, even if done deliberately, poses a risk to the patient from tumor spillage.[92] Regardless, one must be cognizant of a possible bladder perforation when performing aggressive resections.

Skolarikos and colleagues attempted to determine the impact of bladder perforation during TURBT on extravesical tumor recurrence by examining the records of over 3400 patients.[93] They found the incidence of perforation to be only 1% and identified several risk factors associated with extravesical tumor recurrence. The most significant risk factor was the need for an open surgical repair of the perforation, followed by the bladder defect being located intraperitoneally, and the tumor size being in excess of 3 cm.[93] They also noted that patients with extravesical disease after perforation repair fared far worse than the rest of the cohort. In contrast, other studies examining outcomes after TURBT-associated perforation did not detect an increase in extravesical disease frequency or poorer outcomes.[39,95]

Golan and colleagues performed a retrospective review of TURBTs performed at their institution from 1996 to 2008. They identified 15 patients who required open surgical repair of their bladder perforation. They found that bladder perforation requiring open surgical repair is more likely to occur in elderly patients with posterior wall tumors who had prior TURBTs and prior intravesical instillations.[96]

While rare, it seems plausible that perforation during TURBT can lead to extravesical disease, which carries with it a dismal prognosis. It is unclear if perforation should prompt consideration of systemic treatment in an attempt to mitigate any increased risk of soft tissue seeding.[93] Additionally, the use of postresection intravesical chemotherapy is contraindicated in the presence of perforation. The loss of the demonstrated risk-reduction benefit of postoperative intravesical chemotherapy combined with a theoretical increase in disease progression due to perforation reinforces the severity of this complication.

TRANSURETHRAL RESECTION SYNDROME

While TUR syndrome is covered in-depth in Chapter 26, there are several differences in its etiology and presentation that should be considered when this complication arises after TURBT. Post-TURBT hyponatremia is usually due to bladder perforation and the extravasation/extravesical absorption of irrigant fluid, in contrast to absorption across open prostatic venous sinuses during TURP. Since the irrigant is not being directly introduced into the patient's circulatory system and must be absorbed across the peritoneum, the initial presentation may be delayed. Dorotta and colleagues report a case series of four such events and noted that the time to serum sodium nadir was 2–9 hours[91] compared to 1–6 hours[97–100] following prostatic resection. Hyponatremia, intravascular hypovolemia with an increase in total body water, hypotension, oliguria, acute renal failure, metabolic acidosis, and mental status changes are all described in TURBT syndrome.[91]

Early detection, rapid assessment, and immediate treatment are critical when faced with this complication. Management is nearly identical to that for TURP syndrome described in Chapter 26. The procedure should be halted, a bladder catheter left in place, "STAT" serum chemistries sent, and resuscitation with normal saline started. The patient's sodium deficit should be calculated and serial measurements made to ensure the proper rate of correction. Use of hypertonic saline poses the risk of central pontine myelinolysis caused by rapid electrolyte and fluid shifts in the brain, and requires consultation with specialists such as in nephrology or critical care medicine. Diuretics (e.g., furosemide) can facilitate hemoconcentration but should only be used in a euvolemic patient. Drainage of the peritoneum or retroperitoneum can be accomplished via an open surgical procedure with simultaneous repair of the bladder perforation or by placement of a percutaneous drain under ultrasonic guidance by interventional radiology; surgical repair of the bladder can then be performed at a later date once the patient has been stabilized. Transferring the patient to a monitored setting such as an intensive care unit is advisable.

INFECTION

Dysuria is common after transurethral bladder surgery, so patients may have difficulty differentiating the expected symptoms from infection. Likewise, a dipstick urine analysis will be difficult to interpret. A short course of postoperative prophylaxis with oral antibiotics is reasonable until the bladder mucosa has had an opportunity to heal.[9] A suspected infection should be cultured immediately. Empiric antibiotics can be started and tailored to the sensitivities once they are available.

URINARY RETENTION

Instrumentation, anesthesia (general, spinal, or epidural), and postoperative narcotics can all lead to acute urinary retention, especially in men. While many patients are discharged from the hospital or surgical center with a catheter in place, most who undergo resection of superficial and/or small to medium lesions may not require an indwelling Foley. Recovery room orders should clearly indicate that patients must void adequately prior to discharge (specify both a volume and the time in which it must be passed), otherwise a urethral catheter should be inserted and an

office voiding trial performed. Men who take alpha-1 antagonists or 5α-reductase inhibitors should continue on their medications at the usual prescribed dose. Urinary retention that occurs weeks to months post-TURBT should be investigated with cystoscopy to evaluate for urethral stricture, bladder neck contracture, or tumor recurrence and managed appropriately.

THE EFFECT OF TRAINEE PARTICIPATION ON TRANSURETHRAL RESECTION OF BLADDER TUMOR COMPLICATIONS

Transurethral resections of bladder tumor are frequently done in an academic setting and involve residents or fellows who are learning to perform the procedure. Nieder and colleagues prospectively evaluated all TURBTs performed in part by residents or fellows under direct attending supervision. Intraoperative complications were evaluated. Of the 173 TURBTs performed at their institution there were 10 complications including four patients with hematuria requiring transfusion, six extraperitoneal perforations, and two intraperitoneal perforations. This was a complication rate of 5.8%, which is comparable to other studies that did not include residents.[94]

In contrast, Allard and colleagues performed an analysis of all transurethral surgeries (including both TURPs and TURBTs) in the NSQIP user files.[101] They assessed the effect of trainee involvement comparing post graduate year (PGY) 1-2, PGY 3-4, PGY 5, and above versus attending-only resections. In multivariate analysis they found that resident involvement increased the operative time and hospital readmissions within 30 days. Resident involvement was not associated with increased overall complications or need for reoperation.[101]

Complications of Post Transurethral Resection of Bladder Tumor Intravesical Chemotherapy

Several series have shown that intravesical chemotherapy (e.g., mitomycin c) administered in the immediate postoperative period provides a significant reduction in cancer recurrence (50% at 2 years) for patients with superficial disease.[102–105] It is recommended that patients receive such treatment within 6 hours of resection unless there is suspicion of bladder perforation or the patient has an allergy to the chemotherapeutic agent of choice.[106]

The common side effects of intravesical chemotherapy include irritative voiding symptoms consistent with cystitis (dysuria, frequency, and hematuria).[107] All of the agents currently used can result in fibrosis and contracture of the bladder, usually due to chronic exposure, and thiotepa has been shown to cause bone marrow suppression if absorbed.[108] Operating room and postanesthesia care unit staff must also be educated regarding the safe administration, monitoring, and disposal of intravesical chemotherapy agents and supplies. Intravesical BCG is absolutely contraindicated in the postoperative setting; use of this agent can result in systemic sepsis (BCG-osis) and death. BCG should not be given until the bladder epithelium has been allowed to heal for at least 14 days and gross hematuria has resolved.[109]

Conclusions

Transurethral resection of bladder tumor continues to play an integral role in the management of bladder cancer. Careful preoperative preparation, attention to operative technique, and diligent postoperative monitoring and follow-up will help decrease the risk of morbidity and mortality while maximizing patient benefit.

References

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Chapter 25 Questions

1. At the start of your first case, a transurethral resection of bladder tumor (TURBT), no current is produced when the resectoscope foot pedal is pressed. Which of the following actions should you take?
   a. Confirm that the patient is appropriately grounded
   b. Check that the electrocautery generator is plugged in/properly connected
   c. Ensure that the resectoscope is properly connected to the generator
   d. Confirm that the irrigant being used is not saline
   e. All of the above

2. You are performing a TURBT on a man with a tumor in the expected location of the right ureteral orifice (UO). The left ureteral orifice is clearly visible. Which of the following options is most appropriate?
   a. Have the anesthesia team give a diuretic, such as furosemide, in an attempt to see urine effluxing from the right UO
   b. Attempt blind catheterization of the obscured UO with a Bentson guidewire
   c. Resect the tumor using pure cutting current
   d. Abort the procedure and order an intravenous pyelogram (IVP) to better define the anatomy
   e. Do not resect the tumor but instill intravesical chemotherapy instead

3. Which of the following laboratory studies is mandatory prior to TURBT?
   a. Liver function tests (LFTs)
   b. Complete blood count (CBC)
   c. Basic metabolic panel/Chem-7
   d. Urine culture
   e. Coagulation studies (PT/PTT/INR)

4. When endoscopically managing a tumor located on the anterior wall of the bladder, the surgeon should do which of the following to facilitate resection?
   a. Apply anterior-to-posterior suprapubic pressure with the nonoperative hand
   b. Increase the height of the irrigant fluid in order to maximally distend the bladder
   c. Increase the electrocautery current settings
   d. Select a larger resectoscope loop
   e. Perform "blind" resection (i.e., without direct visualization of the tumor)

5. Four hours after the completion of a large, deep, complex TURBT, you are called by a nurse in the ambulatory surgery center about your patient. He reports that your patient is lethargic and clumsy with an altered mental status. Which of the following should be done immediately?
   a. Evaluate the patient
   b. Obtain STAT serum chemistries
   c. Confirm the type of irrigant used during the resection
   d. Review the patient's history and recent medications administered
   e. All of the above

6. An elderly woman who underwent a TURBT for tumor at the bladder dome complains of significant abdominal pain shortly after the procedure. Which of the following studies is most helpful in ruling out a serious complication?
   a. Renal ultrasound
   b. Cystogram
   c. CBC
   d. Abdominal free air series
   e. Repeat cystoscopy

7. At the completion of a TURBT, there is some oozing from the resection bed but hemostasis appears adequate. During emergence from anesthesia, the patient "bucks" against the endotracheal tube and his blood pressure increases significantly. In the PACU frank blood is draining from the Foley catheter. Irrigation with normal saline is initiated but the bleeding persists, eventually resulting in hemodynamic instability. The best course of action is:
   a. Place the Foley catheter on tension
   b. Instill Amicar intravesically
   c. Overdistend the bladder with saline to tamponade the bleeding vessels
   d. Take the patient back to the OR for repeat cystoscopy/clot evacuation/fulguration
   e. Perform an angiogram to localize the bleeding

8. When resecting a tumor on the lateral wall of the bladder, the risk of sudden leg adduction (obturator reflex) can be lessened by which of the following?
   a. General anesthesia with the use of a paralytic
   b. Preoperative percutaneous obturator nerve block
   c. Endoscopic (pre-TURBT) injection of the tumor base with local anesthetic
   d. Use of intermittent electrocautery during resection
   e. All of the above

9. Which of the following is a contraindication to immediate post-TURBT intravesical chemotherapy, such as mitomycin C?
   a. Tumor resected from multiple areas within the bladder
   b. Planned re-TURBT in 2 weeks for additional staging information
   c. Patient age >80 years
   d. Suspected small perforation when the deep resection margin was biopsied
   e. Outpatient surgery status (patient is to be discharged the day of surgery)

10. Informed consent for TURBT should include which of the following risks:
    a. Bleeding
    b. Infection
    c. Bladder perforation
    d. Need for additional surgery/procedures/treatments
    e. All of the above

Case Studies

CASE 1

You are managing a 73-year-old woman who has undergone one previous TURBT for superficial bladder cancer that was resected in its endoscopic entirety. She returns to your clinic after spending the winter in Florida; she recently had an episode of gross hematuria but did not seek medical attention or contact your office. Her urinalysis is positive for microscopic hematuria but negative for signs of infection. Office cystoscopy reveals recurrent disease at the dome, a larger tumor on the left lateral wall, and several papillary fronds near the left ureteral orifice.

1. What course of action would you suggest to your patient?
   a. Intravesical BCG
   b. Renal ultrasound
   c. Intravenous gemcitabine/cisplatin systemic chemotherapy
   d. Transurethral resection of the bladder tumors in the operating room
   e. Bladder biopsy only

This patient undergoes the appropriate preoperative evaluation and is consented for TURBT with intravesical chemotherapy. She does not have significant cardiovascular or pulmonary disease. The anesthesiologist contacts you to see if you have a preference regarding the type of anesthetic he uses.

2. You reply:
   a. The anesthesia team can choose the method they feel is best
   b. Let the patient decide
   c. General anesthesia
   d. Conscious sedation
   e. Spinal anesthesia

You suggest that general anesthesia be used so that a muscle relaxant (paralytic) can be used to prevent stimulation of the obturator nerve during the resection of the left lateral wall tumor. Alternatively, a percutaneous obturator nerve block could be performed preoperatively or local anesthetic could be infiltrated into the base of the tumor endoscopically.

You decide to resect the tumor at the dome first. This is facilitated by applying downward suprapubic pressure (anterior to posterior) with your nonoperative hand. Once the resection is complete, a cold-cup biopsy of the deep margin is obtained and submitted separately to pathology.

3. Which of the following is most accurate with regard to managing the several small papillary fronds around the left ureteral orifice?
   a. Do not treat this area surgically because it could result in ureteral obstruction
   b. Use cold-cup biopsy forceps to remove the tumors and focal electrocautery to fulgurate the tumor base
   c. Resect the entire ureteral orifice using a blended cutting/coagulating current
   d. Fulgurate the area copiously with a high level of coagulating current and then place a retrograde ureteral stent
   e. Attempt to pass an access catheter into the ureter at the conclusion of the case to ensure the ureteral orifice is open

You now turn your attention to the largest tumor located on the left lateral wall. The tumor is fairly vascular and it takes longer than anticipated to resect it completely and obtain hemostasis even though you have been using sterile water as the irrigant. At the conclusion of the procedure you place a three-way Foley catheter for continuous bladder irrigation because of your concern for clot retention. The total procedure time is now over 1.5 hours.

4. In this setting, what intravesical chemotherapy should be used?
   a. BCG
   b. Thiotepa
   c. Mitomycin C
   d. Gemcitabine
   e. No intravesical therapy

The nurses from the ambulatory care unit call to inform you that the patient has not been making adequate urine. They were concerned that her Foley was clotted so they have been vigorously irrigating her catheter by hand with a 60-mL catheter-tipped syringe. When you review the nursing flowsheets you see a sizeable discrepancy between the volume of saline placed into her bladder and what has been documented in the Foley bag. Her abdomen is obviously distended, and she states that she feels bloated. She is mentating appropriately.

5. To investigate the most likely cause of these findings you should:
   a. Obtain a KUB x-ray
   b. Order a CT scan of the abdomen and pelvis
   c. Perform flexible cystoscopy at the bedside
   d. Obtain a cystogram
   e. Obtain an ultrasound

The diagnostic evaluation reveals a perforation at the dome, likely caused by the deep biopsy performed after the tumor was resected, with extravasation of contrast into the peritoneum.

6. The next steps to take include:
   a. Ensure adequate bladder decompression, stop intravesical irrigation
   b. Emergent surgery
   c. Obtain STAT laboratory studies, specifically serum sodium
   d. Monitor the patient closely for signs of TURBT-syndrome
   e. All of the above

CASE 2

Two hours after completing cystoscopy, biopsies, and fulguration of several erythematous bladder lesions in a

68-year-old diabetic man who has a 50-pack/year history of cigarette smoking, you are notified that your patient is febrile to 39.2°C, tachycardic, and hypotensive.

1. You next:
   a. Evaluate the patient
   b. Review his preoperative laboratory studies
   c. Confirm that he received the ordered preoperative antibiotic prophylaxis
   d. Perform urine culture if it was not performed preoperatively
   e. All of the above

You note that his procedure was originally scheduled for 1 month ago. His case was cancelled because the patient was ill with a viral upper respiratory infection. His urinalysis was negative 2 weeks prior to that date but another more recent sample was never sent. Ciprofloxacin 400 mg IV was administered, as ordered, prior to the procedure.
When you evaluate the patient he is pale, diaphoretic, tachycardic, and complaining of chills. His blood pressure is 84/54 mmHg but he is alert and oriented.

2. Appropriate management includes:
   a. Fluid resuscitation and transfer to an appropriate setting for monitoring
   b. Blood and urine cultures
   c. Broad-spectrum intravenous antibiotics
   d. Admit patient for observation
   e. All of the above

Answers

1. **e.** Each of the options above is a common point of equipment malfunction resulting in a loss of current.
2. **c.** Resecting a tumor at the ureteral orifice should be performed carefully with a pure cutting current with the goal of removing all suspicious tissue. The patient should be monitored closely for signs/symptoms of ureteral obstruction or symptomatic vesicoureteral reflux.
3. **d.** While each of these tests may be indicated in many if not most patients, documenting that the patient has sterile urine prior to undertaking transurethral surgery is mandatory.
4. **a.** Applying suprapubic pressure with one's nonoperative hand in the anterior-to-posterior direction over a partially filled bladder can bring a tumor on the anterior wall into view.
5. **e.** TURBT syndrome is a severe complication that must be recognized and managed promptly.
6. **b.** A suspected bladder perforation is best assessed by a cystogram.
7. **d.** Post-TURBT hemorrhage that results in hemodynamic instability is best managed in the operating room by repeat cystoscopy, clot evacuation, and fulguration.
8. **e.** Stimulation of the obturator nerve during TURBT can result in imprecise resection, increased bleeding, and bladder perforation. Appropriate preprocedure planning based on tumor location can minimize this risk.
9. **d.** Bladder perforation is a contraindication to intravesical chemotherapy. BCG is *never* used in the immediate postoperative setting due to the risk of absorption, sepsis, and death.
10. **e.** While TURBT is a commonly performed and usually well-tolerated procedure, it is associated with risks ranging from bleeding, infection, and bladder perforation.

CASE 1

1. **d.** Resection is indicated, in the setting of recurrent superficial bladder cancer, prior to consideration of any form of intravesical therapy. Given the described presence of tumor in the dome, and a large tumor in the lateral wall of the bladder, the resection in the operating room is most appropriate, and more likely to be efficacious than office resection. Bladder biopsy prior to resection would not alter management in this setting. Ultrasound to rule out hydronephrosis would only be indicated if obstruction is suspected.
2. **c.** General anesthesia should be used so that a muscle relaxant (paralytic) can be used to prevent stimulation of the obturator nerve during the resection of the left lateral wall tumor. Alternatively, a percutaneous obturator nerve block could be performed preoperatively or local anesthetic could be infiltrated into the base of the tumor endoscopically.
3. **b.** Since there are only a few frond-like tumors near the UO, they can be removed with the biopsy forceps and hemostasis obtained with focal electrocautery. If the UO was involved extensively, resecting the tumor with a pure cutting current is appropriate. Postoperatively, a percutaneous nephrostomy tube could be employed if ureteral obstruction occurred.
4. **e.** Bleeding that requires the use of continuous bladder irrigation (CBI, also known as a Murphy drip) is a contraindication to intravesical chemotherapy. BCG should never be used in the immediate postoperative setting.
5. **d.** Given the presence of decreased urethral catheter output and return of irrigant, along with increasing abdominal distention, an intraperitoneal bladder rupture at the site of dome resection should be considered. This may have been the result of undetected perforation at the time of resection, secondary perforation at the time of clot retention in the recovery room, or overly aggressive irrigation. In this setting, a cystogram would be he most likely to demonstrate the presence of a perforation, along with its size and location. A CT scan of the abdomen can be informative, and might demonstrate urinary ascites in this case, but it would not likely be diagnostic without a distention cystogram performed simultaneoulsy (CT cystogram would also be an acceptable test to consider).
6. **e.** This patient is at risk for TURBT syndrome, peritonitis, and up-staging of her disease. The sterile water irrigant used during the resection, as well as the normal saline from the postoperative CBI, will need to be removed from the peritoneal space and the bladder defect repaired. This can be accomplished through either an open or laparoscopic approach, based on the

experience and preference of the surgeon. The patient should be consented for emergency surgery and returned to the OR as soon as possible.

CASE 2

1. **e.** It is critical to ensure that the patient's urine is sterile prior to undergoing any transurethral surgery whenever possible.
2. **e.** Urosepsis must be promptly identified and aggressively managed. Sepsis can trigger other complications such as demand-mediated myocardial ischemia, renal failure, coagulopathy, etc.

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26 Complications of Endoscopic Procedures for Benign Prostatic Hyperplasia

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CHAPTER OUTLINE

Introduction
Nonspecific Complications of Endoscopic Procedures for BPH
Intraoperative
- Intraoperative Bleeding
- Transurethral Resection Syndrome
- False Urethral Passage
- Injury to the Bladder or Ureteral Orifices
- Injury Beyond the Prostate
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Postoperative
- Postoperative Bleeding
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- Urethral Stricture
- Bladder Neck Contracture
- Meatal Stenosis
- Retrograde Ejaculation
- Erectile Dysfunction
- Need for Retreatment

Miscellaneous
Conclusions
Chapter 26 Questions and Answers

KEY POINTS

1. While there are multiple ways to approach the surgical management of benign prostatic hyperplasia (BPH), endoscopic techniques are by far the most common.
2. Endoscopic techniques to manage BPH include transurethral microwave therapy (TUMT), transurethral needle ablation (TUNA), prostatic urethral lift (PUL), transurethral resection of the prostate with monopolar or bipolar energy, bipolar vaporization of the prostate, transurethral incision of the prostate (TUIP), laser vaporization of the prostate, and laser enucleation of the prostate.
3. Complications of endoscopic BPH surgery that patients should be counseled on preoperatively include bleeding, transurethral resection syndrome, infection, injury to adjacent structures such as the bladder or ureteral orifices, urinary incontinence, urethral stricture, bladder neck contracture, meatal stenosis, erectile dysfunction and retrograde ejaculation.
4. Overall, the incidence of most of these complications is quite low with the exception of retrograde ejaculation which occurs at a rate of 50% or higher with many approaches. TUIP, PUL, TUNA, and TUMT preserve ejaculatory function at a higher rate.
5. It is essential to understand the risk of surgical complications by procedure type and adequately counsel patients as to these risks as part of a shared decision making process. Knowledge of landmarks, excellent technique, and careful patient counseling will minimize complications, result in excellent outcomes, and increase patient satisfaction.

Introduction

Benign prostatic hyperplasia (BPH) is one of the most common diseases of aging men. Fifty percent of men between the ages of 51 and 60 years old have pathologic benign prostatic hyperplasia.[1] Surgical treatment options for BPH include open, laparoscopic, endovascular, and endoscopic techniques. Open and laparoscopic simple prostatectomy techniques have the disadvantages of being more invasive, with a higher risk of blood loss, and the need for prolonged catheterization and hospitalization.[2–5] These approaches are reserved for very large prostates, typically greater than 80–100 g. Recently, prostatic arterial embolization has gained some interest as a minimally invasive approach to the management of BPH.[6] Further studies are necessary to validate the effectiveness and durability of this approach.

Endoscopic techniques comprise the most common approach for the surgical management of BPH. These endoscopic procedures include monopolar and bipolar transurethral resection of the prostate (TURP) (mTURP and bTURP, respectively), bipolar vaporization of the prostate (BVP) using the mushroom electrode, laser vaporization/ablation, laser enucleation of the prostate, transurethral incision of the prostate (TUIP), transurethral microwave therapy (TUMT), transurethral needle ablation therapy (TUNA), and prostatic urethral lift (PUL). Techniques such as interstitial laser coagulation and transurethral ethanol injection are antiquated, rarely performed, and will not be reviewed here. This chapter will focus on the prevention and management of complications following the aforementioned endoscopic procedures for BPH. When reviewing laser vaporization procedures or photovaporization of the prostate (PVP), the discussion will focus on GreenLight laser (Boston Scientific, Marborough, MA), also known as the potassium titanyl phosphate (KTP) laser, as it is the most utilized laser for this approach. Similarly, in terms of enucleation procedures, this chapter will focus on holmium laser enucleation of the prostate (HoLEP). The safety and efficacy of thulium and diode lasers for prostatic enucleation are currently being studied and compared to HoLEP. The rates of well-studied complications are reported in Table 26.1 and Table 26.2.

Table 26.1 Perioperative Complications

	Blood Transfusion	TUR Syndrome	Capsular Perforation
mTURP	1.5–20%[32,34,62,97–100]	1.8–21%[32,34,97,98]	2.7–16.7%[34,97,100]
bTURP	0–2.7%[33,34,99–102]	0%[32,33,97]	7.1%[97]
HoLEP	0–1.8%[45,51,62,98,103]	0–6.1%[45,51,63,98]	1.5–9.6%[45,51]
PVP	0–1.5%[34,99–102]	0%[34,100–102]	0–3%[34,100,104,105]
BVP	0–1.2%[97,106]	0%[97,106–108]	1.2%[97]
TUIP	1.1%[91]	0%[91]	0%[104]

bTURP, bipolar TURP; BVP, bipolar vaporization of the prostate; HoLEP, Holmium laser enucleation of the prostate; mTURP, monopolar TURP; PVP, photoselective vaporization of the prostate; TUIP, transurethral incision of the prostate

Nonspecific Complications of Endoscopic Procedures for BPH

INTRAOPERATIVE

Intraoperative Bleeding

The prostate is a highly vascular organ and some degree of bleeding is expected during any surgical approach to BPH. Hemorrhage is the main cause of surgical vision loss, which can lead to prolonged operative time, capsular perforation, fluid absorption, and excessive use of irrigation fluids, all of which are risk factors for transurethral resection syndrome (TURS) and sepsis.[7] The risk of bleeding increases with larger prostate size, longer operative time, increasing tissue resected, general anesthesia, positive urine culture, indwelling catheter, and the use of antiplatelet therapy or anticoagulation.[7–12] While several older series have demonstrated less blood loss with regional anesthesia, the mechanism for this is not well understood.[13,14] The rate of blood transfusion following endoscopic BPH surgery is low and depends on the type of procedure performed (see Table 26.1). A meta-analysis comparing HoLEP and TURP found a lower transfusion rate in those undergoing prostatic enucleation.[15]

Several steps can be taken preoperatively to decrease the risk of excess bleeding and potential blood transfusion. First, platelet count and coagulation panel are obtained and any abnormalities addressed preoperatively. Assessing for preoperative anemia will aid in counseling the patient on the risk of perioperative blood transfusion. A type and screen should be sent preoperatively to facilitate timely transfusion if necessary. Second, if the patient is taking antiplatelet therapy or anticoagulants, a discussion must take place with his primary care provider (PCP) as to whether it is safe to hold and/or bridge these medications. If the procedure must be done on antiplatelet or anticoagulants, then laser and bipolar techniques have been shown to provide the best hemostasis.[16–18] Men undergoing PVP and bTURP have less bleeding, need for blood transfusions, and postoperative clot retention compared to those undergoing monopolar TURP in some series.[19,20] Preoperatively, the patient is carefully counseled on the risk of bleeding. If

Table 26.2 Postoperative Complications[20,32–34,45,51,62–64,77,82,88–91,94,97–174]

	Urinary Tract Infection	Urethral Stricture	Bladder Neck Contracture	Stress Incontinence	Retrograde Ejaculation	Erectile Function		Retreatment
						Worse	Better	
mTURP	2–13.5%	1.1–10%	1.1–12%	1.1–2.2%	57–86%	28%	23%	0–4%
bTURP	0–10.5%	0.8–2%	0–6.6%	0–2.5%	4.5–66.6%	2.2–17%	10.1–28.2%	0–9.4%
HoLEP	0–3.2%	1.7–4.1%	0.4–3.9%	0.7–1.7%	74–78%	11–12%	3–7%	0–1.4%
PVP	0–17%	0–5.1%	0–7.4%	0.8%	49.9%	10%	20%	4.3–11%
BVP	2.4–10%	0–6.8%	0–8%	0–11.7%	59.2–82%	12–13%	nwd	0–43%
TUIP	0–9%	2.4–21.5%	0–2.1%	0–11%	0–35%	0–6.25%	12.5%	4–34.8%
TUMT	0–33%	0–2%	0%	0%	0–22.2%	0–9%	0–15.2%	2.2–32%
TUNA	4–14%	0–1.5%	nwd	0–1.5%	0–15%	0–3%	nwd	9.75–31%
PUL	2.9–12.12%	0%	0%	0%	0%	0%	nwd	1.9–20%

bTURP, bipolar TURP; BVP, bipolar vaporization of the prostate; HoLEP, Holmium laser enucleation of the prostate; mTURP, monopolar TURP; nwd, not well described; PUL, prostatic urethral lift; PVP, photoselective vaporization of the prostate; TUIP, transurethral incision of the prostate; TUMT, transurethral microwave therapy; TUNA, transurethral needle ablation

the risk of bleeding is high due to medical comorbidities and/or the need to remain on blood thinners, medical therapy or management with catheterization may be more prudent. The use of 5α-reductase inhibitors prior to TURP has not consistently been shown to reduce blood loss or the need for transfusion, and thus this approach in an attempt to reduce perioperative bleeding is not recommended by the AUA guidelines.[21–25]

Intraoperative techniques to prevent bleeding complications include avoiding capsular perforation and entry into venous sinuses where bleeding is difficult to control. Additionally, controlling bleeding vessels as they are encountered and aiming for a shorter operative time will result in less blood loss. If electrocautery is being used some advocate first fulgurating all of the friable mucosa with the button electrode to prevent bleeding from this friable tissue prior to loop resection of adenoma.[26]

When significant intraoperative bleeding is encountered, the best way to obtain hemostasis, decrease blood loss, and avoid the need for a staged procedure is to advance the scope into the bladder and slowly pull it back into the prostatic fossa to identify the bleeding vessels and fulgurate or laser. If arterial bleeding is directed straight at the lens, an optimal angle to visualize the bleeding stump must be found to achieve hemostasis.[12] Simultaneous digital rectal manipulation may help to expose vessels over the prostate floor.[12] Venous bleeding is usually dark red and may be found in areas of capsular perforation.[12,27] Small venous bleeders can be controlled with direct pressure from a three-way Foley catheter. Excessive coagulation is avoided in areas of capsular perforation to decrease the risk of aggravating this defect. Hemostasis is assessed at the end of the case with the bladder minimally full, irrigation flow off, and patient normotensive. Hypotension at the end of the procedure can mask arterial bleeding. Blood work can be performed intraoperatively as well to monitor for anemia if there is concern for significant blood loss.

Transurethral Resection Syndrome

TURS is a serious and potentially life-threatening complication of mTURP as one of the requirements of monopolar resection is the use of hypotonic fluid, typically glycine or sorbitol. TURS occurs with early perforation of the capsule and venous sinuses resulting in the absorption of hypotonic solution and a dilutional hyponatremia. These patients can be confused and disoriented and may experience nausea, vomiting, seizures, blurred vision, bradycardia, and hypotension. The incidence of mild-to-moderate TURS has decreased during the last few decades from 0.5–8% to 0–1.4% secondary to the use of saline irrigant with laser and bipolar techniques.[9,28–35] Several meta-analyses of monopolar and bipolar resection have reported a significant decrease in TURS, with no patient developing TURS following bTURP.[19,36]

TURS may be seen from as early as 15 minutes after the start of resection and up to 24 hours postoperatively.[37,38] Hyponatremia can be very severe and result in significant morbidity and even mortality at a rate up to 50% when the sodium concentration drops below 120 mEq/L.[39] Hyponatremia and hypoosmolality result in acute cerebral or bronchial edema secondary to large absorption of fluid and expansion of extracellular fluid. TURS most commonly occurs when 1.5% glycine is used as the irrigant fluid during mTURPs. This irrigant is nonconductive, nonhemolytic, and hypotonic with an osmolality of about 220 mmol/L irrigant. Excessive absorption of glycine solution results in TURS in 5–20% of mTURPs.[40]

The best way to prevent TURS is to avoid endoscopic procedures using hypotonic solutions. If mTURP must be performed, then it is important to avoid deep resections and extravasation, which will increase the amount of fluid absorbed. If a venous sinus is opened or capsular perforation has occurred, hemostasis is achieved and the procedure aborted. When performing mTURP, even if capsular perforation or major venous sinuses are not encountered, the procedure is generally limited to 60–90 minutes in order to minimize the amount of fluid absorbed and decrease the risk of TURS. Therefore, if a larger prostate is approached with TURP, the patient is counseled that he may need to be treated in a staged manner and if the prostate is very large, a simple prostatectomy can be considered if mTURP is the only endoscopic surgical option. During the procedure, anesthesia may periodically send blood gases to check electrolytes and the procedure may be aborted if the serum sodium is low.

Besides limiting operative time and selecting patients with smaller prostate volumes, another method to prevent TURS includes minimizing irrigant fluid pressure.[40,41] Techniques that have been described to decrease fluid pressure at the time of TURP include the standard use of a continuous flow resectoscope that allows drainage out of the scope (Iglesias), suprapubic fluid evacuation using a Reuter's trocar or via suprapubic catheterization, and intermittent drainage of irrigant fluid.[37,40] Irrigation fluid is always kept on gravity and not placed under pressure. The urologist can also attempt to monitor fluid absorption. This is done by calculating the difference between irrigation fluid used and the volume of fluid that drains from the resectoscope and into the collection bag. Accurate measurement of fluid absorption may be challenging given the mixture of blood and urine and the inevitable spillage of irrigant fluid onto the floor.

It is prudent to monitor the serum sodium postoperatively for TURS for all men undergoing endoscopic BPH treatments when hypotonic fluids such as glycine are used. If serum sodium is only mildly decreased (about 5 mEq/L) on postoperative lab work and the patient is asymptomatic, then no specific therapy is indicated. If renal function is normal, then the hyponatremia will correct with the natural excretion of excess water. If there is concern for pulmonary congestion, a loop diuretic can be given. The management of patients with symptomatic hyponatremia is variable depending on the severity. For patients with severe hyponatremia, low serum osmolality, and/or cerebral edema, hypertonic saline can be considered. Hypertonic solution reduces cerebral edema and replaces urinary sodium losses that result from the osmotic diuresis that occurs with glycine, mannitol, or sorbitol. This osmotic diuresis perpetuates hyponatremia and results in hypotension secondary to hypovolemia.

Hypertonic saline can initially be administered as a 100-mL bolus of 3% saline, giving 51 mEq of sodium, which will increase serum sodium by 2–3 mEq/L. If

symptoms do not improve, 100-mL boluses can be given one to two more times in 10-minute intervals.[42] Given the acute onset and short duration of hyponatremia in patients following endoscopic BPH surgery, rapid correction of hyponatremia and hypoosmolality is generally safe, unlike in those with chronic hyponatremia who are at risk for central pontine demyelination with rapid correction of serum sodium. For patients with hyponatremia and normal serum osmolality, hypertonic saline has not been shown to be beneficial and actually there have been reports of delayed osmotic demyelination.[43] Hemodialysis (HD) can rapidly correct hyponatremia, osmotic abnormalities, and volume status. HD may be preferred in those with chronic kidney disease, marked hyponatremia without significant osmolality abnormalities, or those with severe neurologic symptoms.[44] Ultimately, nephrology should be consulted as well to assist with the management of symptomatic electrolyte abnormalities, fluid overload, or refractory hyponatremia.

False Urethral Passage

A false urethral passage is an iatrogenic defect somewhere along the course of the urethra. This complication probably occurs more frequently than is reported in the literature. One series reported this complication in 0.5% of men undergoing endoscopic surgery for BPH.[45] This can happen with blind urethral catheter insertion and cystoscope placement. At the time of endoscopic BPH treatment, a false urethral passage may occur if the resectoscope is inserted haphazardly and if inadequate lubrication is used. To avoid this complication, place the scope under direct vision using a visual obturator instead of a blind obturator, especially if any resistance is noted with an attempt at blind insertion. On insertion of the scope, if narrowing or stricturing of the urethral lumen is noted, then the scope can be passed over a catheter or a wire to ensure that it follows the natural lumen and does not go off-course creating a false urethral passage. Additionally, urethral dilation can be performed prior to scope placement to facilitate successful passage. The Foley catheter may be left in place for a few more days postoperatively in the setting of a significant false passage.

Injury to the Bladder or Ureteral Orifices

Injury to the bladder or ureteral orifices is rare but can occur if one is not careful.[46] Using a surgical table with radiologic capabilities is ideal to allow for cystogram and ureteral stent placement if these complications do occur. Bladder perforation has been described for all types of endoscopic BPH procedures and can occur from perforation with the scope, with Ellik evacuation of prostate chips, laser application or transurethral resection beyond the prostate, and at the time of morcellation with enucleation procedures.[46,47] Several case reports describe bladder rupture at the time of TURP related to the ignition of flammable gases created by electrical activity during resection.[48–50]

On initial cystourethroscopy, landmarks are identified including the ureteral orifices. Generally, the ureteral orifices are located between 4–5 o'clock (patient's left side) and 7–8 o'clock (patient's right side) over the trigonal ridge on endoscopic evaluation. Sometimes, when there is significant intravesical tissue – especially from a large median lobe – identification of the ureteral orifices may be very difficult and even impossible. Additionally, on initial inspection the bladder is characterized not only with regard to the presence of trabeculation, stones, diverticula, and mucosal lesions, but also bladder capacity as morcellating in a smaller capacity bladder can be more challenging and potentially dangerous.

Injury to the ureteral orifice has been reported to occur in 0–2% of patients undergoing various endoscopic procedures for BPH.[46,51] Some have suggested suprapubic cystoscopy to help identify the ureteral orifices in some cases, though this technique is rarely employed today.[52] Knowledge of ureteral orifice location relative to the bladder neck will decrease the risk of injury. The ureteral orifices will be closer to the bladder neck when the bladder is underfilled. Familiarity with equipment is essential to avoid complications including where a side-firing laser will penetrate tissue to avoid accidently firing past the bladder neck and causing bladder or ureteral orifice injury. Depending on the degree of ureteral orifice injury, placement of a ureteral stent may be considered to prevent stenosis. If there is concern the ureteral orifice was injured, but the opening cannot be identified, the patient can be monitored for symptoms of obstruction postoperatively. Imaging with renal ultrasound or computerized tomography may be necessary. If hydronephrosis is present, placement of a ureteral stent, nephrostomy tube, or nephroureteral stent can relieve the obstruction. Agents such as indigo carmine, methylene blue, and fluorescein can be used to dye the urine and aid with localization of the ureteral orifice if it is not completely obstructed at the time of cystoscopy.

Bladder injury can also occur if resection, ablation, or vaporization is performed within the bladder. This may happen if visualization is obscured secondary to bleeding, inadequate irrigation, and/or broken equipment. If hemostasis is adequate and visualization is poor, check the irrigation flow and equipment. The irrigant bags can be raised to increase the flow of gravitational irrigation. Sometimes, the outflow port of the continuous flow resectoscope can be obstructed with clot, which will limit the inflow of irrigant. This can usually be fixed by flushing the outflow port.

With enucleation procedures, removal of prostatic tissue is achieved through morcellation. Morcellator injury of the bladder occurs when engagement of the bladder with the morcellator blades is not recognized. Sometimes the bladder mucosa is just engaged by the suction mechanism of the morcellator and not the blades themselves. Superficial bladder mucosal injuries without perforation have been reported in 0.7–5% of cases and bladder perforation in 0–1.5% of cases.[51,53] Anecdotally, the risk of morcellation injury increases with poor visualization, large adenoma in a small capacity bladder, inadequate anesthesia resulting in patient motion during morcellation, and surgeon inexperience. In order to decrease the risk of morcellator injury, it is recommended that both ports of the resectoscope be used as "inflow" ports with irrigation fluid running continuously through both. This allows for adequate distension of the bladder for safe morcellation. If visualization is poor secondary to bleeding, some describe leaving the adenoma in the bladder and coming back 1–2 days later to morcellate when there is better visibility and the tissue is less firm.[54] Some advocate for morcellating the enucleated adenoma in the prostatic fossa to avoid bladder injury.[55] Others recommend a "mushroom" technique where the prostatic lobes

are enucleated but left attached at the bladder neck and then electroresected.[56] This technique is not employed by most urologic surgeons performing HoLEP who have access to a tissue morcellator.

If the bladder becomes engaged in the blades of the morcellator, morcellation ceases. The morcellator is left in place, while the suction is relieved by opening the hinged gate of the roller ball. This will release the bladder from the morcellator blades. Next, examine the bladder carefully. If it was only engaged and not actually cut, proceed with morcellation, and take care to correct whatever caused the bladder to become engaged in the blades. If there is concern for bladder perforation, perform a cystogram on the table to assess for extravasation. If extraperitoneal injury occurred, obtain hemostasis, place a catheter, and abort the procedure. Come back in 1–2 weeks after the bladder has healed to complete the morcellation and or treatment of BPH. If an intraperitoneal bladder injury occurs, then immediate cystotomy repair is recommended. This is typically performed with exploratory laparotomy, though laparoscopic repairs have been reported.[49] In the case of enucleation procedures, the remainder of the adenoma can be extracted from the bladder via the cystotomy prior to repair. A drain should be placed outside the bladder at the time of cystotomy repair.

Injury Beyond the Prostate

Endoscopic BPH procedures can all be complicated by capsular perforation, undermining of the bladder neck, and rarely though potentially morbid, rectal injury. As previously described, capsular perforation (Fig. 26.1) can result in increased fluid absorption and TUR syndrome and potentially erectile dysfunction (ED) secondary to neurovascular bundle injury.

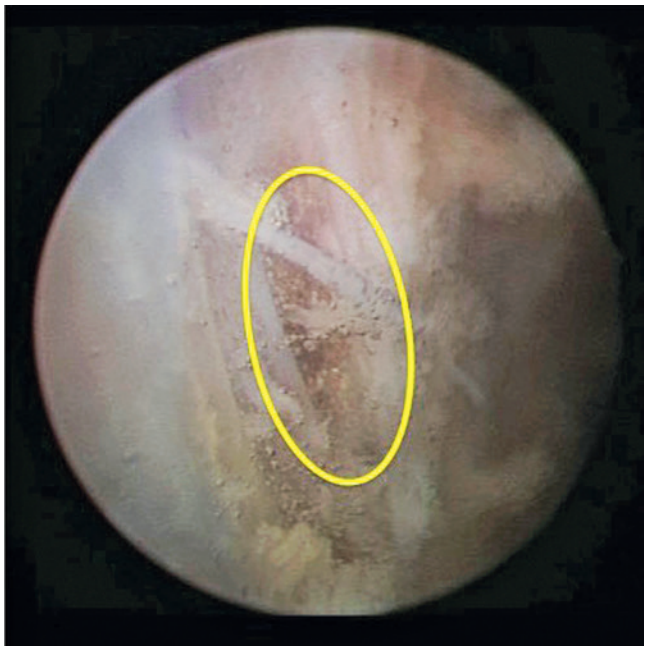


Figure 26.1 Capsular perforation. Small perforation in the prostatic capsule encircled.

In men with significant BPH, it is not uncommon to have prostatic adenoma protruding under the bladder neck and approaching the trigone. This adenoma must be carefully resected, enucleated, or vaporized to avoid undermining and/or perforation. Depending on the extent of undermining and/or perforation, there is the potential to injure the ureters as they insert into the bladder. If significant undermining of the trigone occurs, place the urethral catheter over a wire, otherwise it will likely preferentially pass into this defect, possibly worsening this injury. If the patient fails a voiding trial postoperatively, consider replacing the catheter cystoscopically over a wire, or at least using a coude catheter.

Rectal injury at the time of endoscopic BPH surgery is an incredibly rare but very serious and morbid complication. This can happen when the surgeon carries the treatment plane too far posteriorly. One French study reported their experience with four rectal perforations that occurred at the time of transrectal ultrasound-guided PVP of the prostate in two cases, TURP in one case, and TUIP in another in a series of 450 patients.[57] Rectal injury was managed with either colostomy or primary closure. Ultimately two patients died from this complication and two others were doing well at 1-year follow-up. History of prior BPH surgery, prostatitis, and/or prostatic/rectal abscesses may also increase the risk of this injury. If a rectal injury is noted, abort the procedure and consult a colorectal or general surgeon immediately. Bowel diversion and urinary diversion with suprapubic catheter drainage may be required.

Challenges to Initiating Treatment

At times there are barriers to treatment, which represent situations where the procedure cannot proceed due to some physical obstacle. These difficult situations include patients with phimosis, meatal stenosis, urethral stricture, intraoperative priaprism/penile erection, and excessive urethral length that prohibit passage of the resectoscope into the bladder. We will briefly discuss these situations and how to manage them to facilitate endoscopic BPH treatment.

Phimosis occurs in adult uncircumcised men most commonly when the distal prepuce skin develops scar tissue from chronic inflammation. The scarred tissue loses its elasticity and, if severe, may not allow for retraction of the foreskin beyond the glans of the penis, obscuring visualization of the urethral meatus and prohibiting scope placement. A thorough examination of the phallus and meatus prior to BPH surgery will identify this pathology preoperatively and allow for appropriate counseling and surgical preparation. A dorsal slit may be required to facilitate scope placement and BPH treatment. Circumcision at the time of the operation or on a date prior to BPH surgery may also be considered.

Meatal stenosis identified preoperatively allows for patient counseling for meatal dilation and meatotomy at the time of BPH surgery. Meatal dilation can be facilitated with Van Buren sounds. An Otis urethrotome is an excellent tool to perform meatotomy and will be discussed later in the section describing ways to prevent postoperative meatal stenosis. It is not uncommon to identify concurrent urethral stricture disease in those men with BPH who may have undergone urethral instrumentation for management and diagnosis of BPH. In some cases, the scope can be gently passed through the narrowed urethral segment over a wire or catheter so

as to maintain the lumen. For a more robust stenosis, dilation over a wire with a balloon or sequential urethral dilators with filiforms and followers is usually effective.

Priapism is defined as a persistent erection of the penis not associated with sexual stimulation or desire. Penile erections at the time of transurethral surgery occur in 0.1% to 1% of cases.[58,59] Transiently ceasing stimulation in some cases will return the phallus back to a flaccid state. These series all found that a single dose of phenylephrine given intracorporeally resulted in successful detumescence and allowed for completion of the endoscopic procedure.[58,59] We recommend starting with a dose of 100 to 200 µg of phenylephrine.

Due to significant urethral and penile length, especially in the setting of very large and long prostates or malleable penile prostheses, a resectoscope may not reach the bladder. In these cases, an extra-long resectoscope can be used if available. Another option is to perform a perineal urethrostomy and insert the scope through this opening.[60,61] A perineal urethrostomy can be created by passing a van Buren sound down to the bulbar urethra and incising down onto it. Once the van Buren sound is visible, place stay sutures in the urethra and pass the resectoscope into the bladder for BPH treatment. At the conclusion of the procedure, a Foley catheter is placed into the bladder and the perineal urethrostomy is closed in several layers over the catheter. The catheter is left indwelling for at least 1–2 weeks and a pericatheter retrograde urethrogram (RUG) or RUG following catheter removal is performed to ensure the urethra has healed.

POSTOPERATIVE

Postoperative Bleeding

The rate of postoperative bleeding and hematuria following endoscopic BPH procedures is variable. Some degree of postoperative hematuria is expected following these procedures. However, significant bleeding and hematuria resulting in clot urinary retention and the need for hand irrigation, continuous bladder irrigation (CBI), blood transfusions, and surgical intervention with cystoscopy, clot evacuation, and fulguration is rare. The need for postoperative clot evacuation and fulguration for the management of clot retention ranges from 0% to 2.2%.[51,62–64]

The best way to prevent postoperative bleeding is to obtain excellent hemostasis at the time of surgery. The prostatic fossa is evaluated at the end of the procedure with the bladder minimally full, irrigation fluid off, and any bleeders noted controlled. The patient should be normotensive at the time of evaluation, as hypotension can mask bleeding. Blood thinners and antiplatelet agents are held postoperatively when deemed safe by the patient's PCP.

When significant postoperative bleeding is encountered, many patients can be managed conservatively with hand irrigation, CBI, and serial hemoglobin/hematocrit levels. CBI through a large bore three-way catheter (20–24Fr) helps to stop the bleeding secondary to pressure of the urethral catheter across the resection bed, contraction of the prostatic capsule and prostatic peripheral zone, and vasoconstriction.

Some have reported reduction in postoperative bleeding following TURP by placing the catheter on traction and effectively compressing the prostatic fossa, achieving hemostasis with pressure.[65] Depending on the size of the prostate and amount of tissue resected, one must be sure an adequate amount of fluid is placed in the balloon to avoid migration into the fossa. Others describe digital compression via the rectum on the prostate to tamponade bleeding vessels.[12] If hematuria does not improve with these conservative measures and/or there is significant acute blood loss anemia, evaluation of platelet count and coagulation panel are necessary. Some series have reported severe bleeding associated with disseminated intravascular coagulation following endoscopic BPH treatment.[54] Some patients may require blood transfusions and observation in an intensive care unit with appropriate monitoring and supportive measures. If bleeding persists, ultimately cystoscopy with clot evacuation and fulguration may be required. Some case reports describe the rare need for angiography and embolization when bleeding is refractory to cystoscopy and fulguration.[66]

Infection

Urinary tract infections (UTIs) can occur following any endoscopic urologic treatment and can manifest as a lower UTI, pyelonephritis, prostatitis, prostatic abscess, epididymitis, and/or urosepsis. Patients with indwelling urethral catheters, on intermittent catheterization, with incomplete bladder emptying, prior history of UTI, and diabetes mellitus are at higher risk for bacterial colonization and postoperative infections.[67] One prospective study looking at patients without indwelling urethral catheters or on intermittent catheterization and sterile urine preoperatively reported a 26% rate of postoperative bacteriuria, which was associated with an operating time of greater than 52 minutes and disconnection of the closed urinary drainage system.[68]

In order to prevent postoperative UTIs, a preoperative urine culture is sent and if positive the patient treated with a course of culture-specific antibiotics. The urine culture can be repeated to assure clearance of the bacteria. For patients with negative preoperative urine cultures, AUA guidelines recommend perioperative coverage with fluoroquinolones, trimethoprim-sulfamethoxazole, aminoglycoside ± ampicillin, first- or second-generation cephalosporins, or amoxicillin/clavulanate.[67] However, given the black box warning placed on fluoroquinolones by the Food and Drug Administration in 2016 secondary to the risk of serious side effects, including debilitating tendon injuries, this antibiotic class should be used only when there are no other reasonable alternatives. A course of preoperative antibiotics can be considered in patients with an indwelling catheter or on intermittent catheterization and negative preoperative urine culture, as these patients are at high risk of being colonized with bacteria. It is our practice to change the catheter in the office and send urine for culture from the new catheter. A meta-analysis found that a short course of antibiotics may be superior compared to a single-dose regimen to prevent postoperative UTI.[69] We often extend the course of postoperative antibiotics in patients with positive preoperative urine culture and/or urinary retention requiring an indwelling catheter or intermittent catheterization.

If the patient develops a UTI postoperatively, he can be managed with empiric broad-spectrum antibiotics followed

by a course of culture-specific antibiotics once the urine culture finalizes. Given the black box warning of and rising antimicrobial resistance to fluoroquinolones, including in men with UTIs and prostatitis, alternate empiric antibiotic is preferred.[70] If they are stable, reliable, and have minimal medical co-morbidities they can likely be managed on an outpatient basis. However, patients who are elderly often have significant medical comorbidities, and any signs of sepsis should prompt admission and close monitoring. A Foley catheter may be placed for maximal drainage if systemic infection is suspected.

Rarely an inflammation of the pubic bone can occur following endoscopic BPH surgery. Pubic symphysitis has been described in 0.297% of patients following TURP.[71] This is thought to be secondary to infection, trauma, or impaired blood flow and possibly related to preoperative instrumentation and capsular perforation with sinus or fistula formation. Clinically, these patients complain of severe pain in the pubic region and groin with difficulty walking about 1 month following surgery. A minority present with fevers as well. On physical exam these patients are tender over the pubic bone and groin. MRI and CT imaging may be useful diagnostic adjuncts. Temporary catheterization, supportive measures, and a long course of antibiotics (at least 4 weeks) resulted in complete resolution of symptoms in one series of 12 patients.[71]

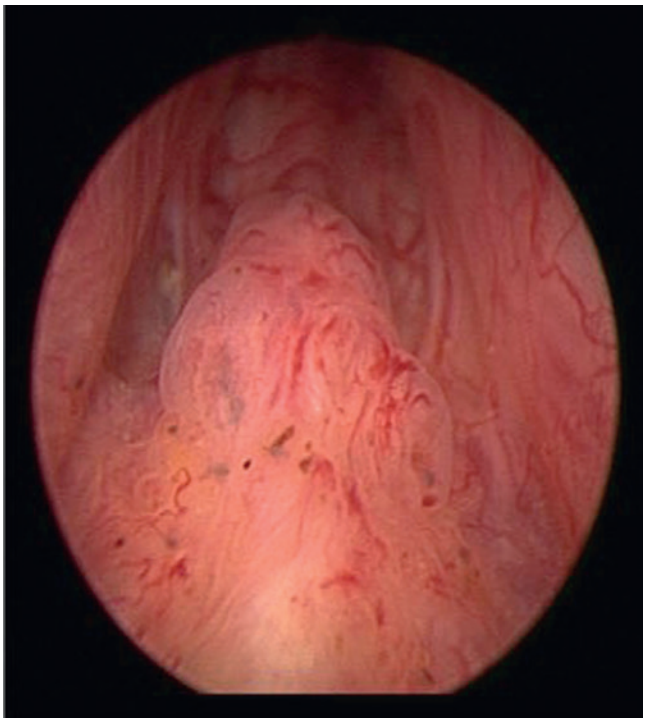


Figure 26.2 Verumontanum.

Urinary Incontinence

Men may experience both stress urinary incontinence (SUI) and/or urge urinary incontinence (UUI) following endoscopic BPH procedures. Transient SUI is not uncommon following most bladder outlet obstruction (BOO) procedures. However, long-term SUI is related to sphincter injury at the time of BPH treatment or preexisting intrinsic sphincter deficiency, which is impossible to determine in the setting of prostatic obstruction. The rate of long-term SUI following endoscopic BPH surgery ranges from 0% to 2.2% (see Table 26.2). In order to prevent long-term SUI the urologist must be cognizant of the location of the external urethral sphincter at all times. The verumontanum (Fig. 26.2) is used as a landmark of the external urinary sphincter, which is an omega-shaped rhabdosphincter. Resection or laser ablation/vaporization distal to the verumontanum should be avoided to prevent injury to the sphincter. For enucleation procedures the laser energy can be reduced when incising the mucosa near the apex of the prostate and blunt enucleation implemented preferentially in this region.

While they are not well studied in men undergoing prostate surgery for benign disease, Kegel exercises are known to improve postoperative urinary incontinence following radical prostatectomy. One series reported a continence rate of 95% versus 65% at 6 months follow-up after radical prostatectomy ($p < 0.001$) favoring those performing postoperative pelvic muscle floor training with Kegel exercises.[72] Many urologists encourage their patients to perform Kegel exercises following endoscopic BPH surgery. For long-term SUI not responsive to pelvic muscle floor training, treatment options include penile compression devices, urethral sling, or artificial urethral sphincter. If the patient is not that bothered, he may elect to use incontinence pads. Cystoscopy is performed prior to surgical intervention to rule out strictures or bladder neck contracture (BNC) that would require treatment before incontinence surgery. If the patient's incontinence is not clearly stress based on history and exam, urodynamic evaluation may be considered prior to surgical intervention.

Irritative lower urinary tract symptoms (LUTS) develop with BPH secondary to long-standing BOO causing detrusor hypertrophy, bladder-wall thickening, and bladder dysfunction. When the obstruction is relieved, some men can develop de novo UUI or exacerbation of preexisting UUI. Some series have found improvement in detrusor overactivity in 30–62% of men following TURP.[73–75] If symptoms persist, medical therapy with anticholinergics, a β_3-adrenergic agonist, or botulinum toxin injections can be trialed.

Urethral Stricture

Urethral stricture can occur anywhere along the urethra following endoscopic management of BPH. The rate of postoperative urethral stricture ranges between 0% and 10% (see Table 26.2). Possible mechanisms leading to urethral stricture following BPH surgery include trauma from resectoscope insertion and monopolar current leakage secondary to insufficient insulation. While one series comparing bTURP versus mTURP noted a significantly higher rate of urethral strictures in the group of men with prostates greater than 70 g undergoing bTURP and contributed this to the differences between bipolar and monopolar energy, a meta-analysis comparing bTURP versus mTURP found no difference in the rate of postoperative urethral stricture.[19,76] This meta-analysis actually found an association of larger prostate size and incidence of postoperative urethral stricture. The authors recommend that larger prostates be treated with HoLEP or simple prostatectomy to avoid this complication. Prostate size and surgical time

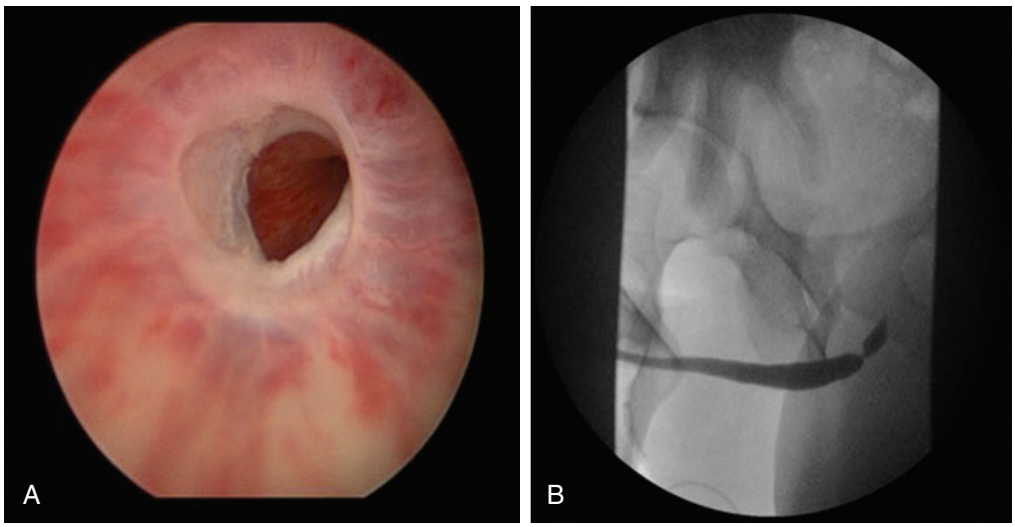


Figure 26.3 Urethral stricture. A, Bulbar urethral stricture on cystoscopy. B, Short bulbar urethral stricture on retrograde urethrogram. (Photographs courtesy of Dr. Douglas F. Milam, MD.)

for HoLEP have not been associated with risk of urethral stricture.[77]

Several studies comparing the size of the resectoscope and postoperative urethral stricture have found an association with larger scope diameter and increased risk of urethral stricture.[78,79] One series evaluating different scope diameters (24Fr vs 26Fr) reported a significantly higher rate of bulbar urethral strictures (11.4% vs 2.9%, $p = 0.018$) with the larger scope.[78] A higher rate of urethral stricture has also been reported in men undergoing retreatment versus primary therapy for BPH (3.3% vs 1.5%, $p = 0.043$).[80] Series localizing urethral stricture report that most occur in the bulbar urethra.[32,78]

Some older series found that patients whose bladders were drained with a suprapubic tube (SPT) following TURP had a lower rate of urethral stricture compared to those drained transurethrally (17% vs 4%).[81] However, in contemporary practice, SPTs are rarely placed at the time of endoscopic BPH treatment unless there is a high risk of permanent urinary retention postoperatively. Other older series also found lower postoperative rates of urethral stricture when prostate resection was performed through a perineal urethrostomy instead of transurethrally.[60] Again – this is rarely performed today unless the resectoscope cannot reach the prostate. To prevent postoperative urethral stricture, great care must be taken to atraumatically insert the resectoscope at the time of surgery. Also, consideration should be given to selecting HoLEP for larger glands and using the smallest diameter resectoscope necessary to perform the procedure safely.

Urethral stricture may be suspected when a patient who initially reported significant improvement in voiding symptoms following a bladder outlet procedure begins to complain of obstructive urinary symptoms. He will likely have a reduction in his urinary flow rate and possibly an elevation in his post-void residual (PVR). Cystoscopy will identify the location and severity of the stricture, and if further characterization is necessary a RUG to help determine stricture length can be performed (Fig. 26.3).

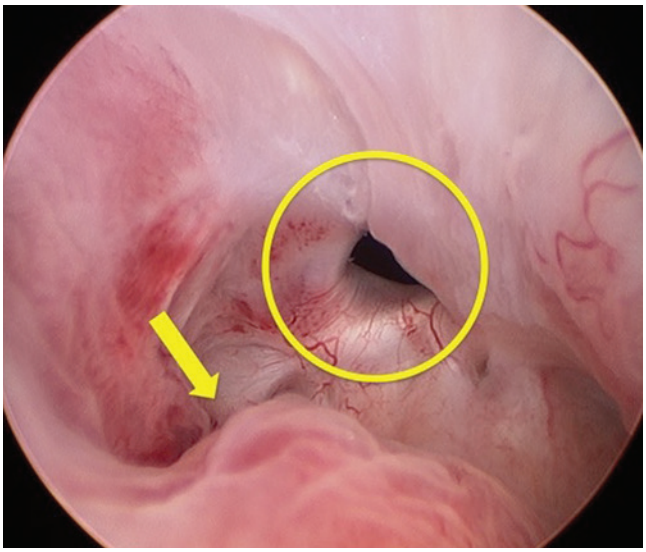


Figure 26.4 Bladder neck contracture. The bladder neck contracture is encircled. The yellow arrow is pointing to the verumontanum. (Photograph courtesy of Dr. Douglas F. Milam, MD.)

Treatment options for postoperative urethral stricture include dilation with sequential or balloon dilators, direct vision internal urethrotomy, urethroplasty, or, in severe cases, perineal urethrostomy. Chronic catheterization is also an option.

Bladder Neck Contracture

BNCs are scar tissue at the bladder neck that can develop following treatment of BPH as well as following radical prostatectomy performed for prostate cancer (Fig. 26.4). The rate of BNC varies by procedure (see Table 26.2). The cause of BNC following endoscopic BPH surgery is attributed to excessive use of cautery around the bladder neck. Pinpoint fulguration is recommended to avoid this complication. Anecdotally, some have found that BNCs following

HoLEP tend to present within the first 6 months after surgery whereas BNC following TURP can present anywhere from 8 months to 36 months postoperatively.[77]

Patients with smaller prostates (<30 mL) and absence of bladder stones are at higher risk of developing BNC following BPH surgery.[82] No difference has been found in the rate of BNC between mTURP and bTURP.[19] A prophylactic bladder neck incision following TURP has been shown to decrease the incidence of BNC postoperatively (12% vs 6%, p = 0.000) with no patient developing BNC if a transurethral incision of the bladder neck was performed and the prostate was greater than 30 g.[82] BNC can be treated with dilation, incision, or transurethral resection. The success rate of endoscopic BNC treatment ranges from 72% to 73%, with a greater than 80% patency rate when a steroid injection is given following incision of the BNC.[83] Rarely patients may require bladder neck reconstruction or even urinary diversion. Chronic catheterization or suprapubic tubes are also an option for surgical failures or in the event the patient is unfit medically.

Meatal Stenosis

Meatal stenosis is a narrowing of the urethral meatus that can be congenital or occur following instrumentation secondary to scar tissue. Meatal stenosis can coexist with fossa navicularis strictures as well. The cause of postoperative meatal stenosis following endoscopic BPH surgery is thought to be secondary to local tissue ischemia from pressure of the scope in a patient with a somewhat narrow meatus at the time of surgery. The rate of postoperative meatal stenosis following endoscopic BPH surgery ranges from 0.8% to 3.7%.[51,84–87] If meatal narrowing or frank meatal stenosis is encountered at the onset of the procedure, Van Buren sounds can be used to calibrate the urethral diameter and for urethral dilation as well. If significant narrowing is encountered, then meatotomy is recommended to prevent pressure necrosis during the case. Meatotomy can be performed with an Otis urethrotome or cold knife incision.[51] Additionally, frequent lubrication of the scope may also help to reduce friction and ischemia at the meatus.

Retrograde Ejaculation

Retrograde ejaculation is when semen is redirected into the bladder instead of out of the urethra. Normally the bladder neck contracts via sympathetic stimulation directing the semen out of the urethra at the time of ejaculation. Retrograde ejaculation or anejaculation can occur both from sympathetic nerve damage at the time of retroperitoneal lymph node dissection or use of alpha-blockers for BPH, as well as from surgery on the prostate and bladder neck. The rate of retrograde ejaculation is quite variable following endoscopic BPH procedures (see Table 26.2) and is best preserved following PUL, with multiple series reporting a 0% rate of retrograde ejaculation.[64,88,89] TUIP also has a relatively low rate of retrograde ejaculation, at 28–35%.[90,91]

Some have studied ways to preserve ejaculatory function following TURP and HoLEP with varying success. The rate of antegrade ejaculation with apical tissue preservation at the time of TURP has been reported to be as high as 90.8%, with comparable improvements in voiding symptoms to standard TURP at 3-month follow-up.[92] However, attempts to preserve the ejaculatory region and ejaculation at the time of HoLEP have been less successful.[93] Patients should be counseled on the risk of retrograde ejaculation with endoscopic treatment of BPH. If maintaining ejaculation is important to the patient, possibly secondary to a desire to maintain fertility, then a procedure with a lower rate of retrograde ejaculation may be best suited for him. He may even want to consider banking his sperm prior to surgery if the ability to father a child later is desired.

Erectile Dysfunction

Studies reviewing the risk of ED following the treatment of BPH have generally found no significant differences between preoperative and postoperative sexual function in terms of intercourse satisfaction and desire.[94] Several series have found mixed outcomes, with some patients reporting improvement in erectile function following BPH treatment and others reporting some decrease in sexual function. Improvement in sexual function may be related to cessation of 5α-reductase inhibitors and alpha-blockers postoperatively. Some series have found an association with postoperative ED and intraoperative capsular perforation.[95,96] This may be secondary to neurovascular bundle injury. Avoiding capsular injury and the cessation of BPH medications may improve erectile function and prevent ED postoperatively.

Need for Retreatment

The goal of endoscopic BPH surgery is to create an open outlet and remove all BPH adenoma. However, in most cases, some BPH tissue in the transition zone is left in order to avoid the complications associated with capsular perforation and deep resection. Over time, benign adenoma can grow back and cause recurrent obstruction and symptoms. Incomplete tissue removal is also possible, especially in the setting of larger glands. Inadequate resection is more frequent in the anterior prostatic fossa.

The rate of retreatment following endoscopic BPH surgeries varies based on procedure type (see Table 26.2). One series on PVP reported an 11% reoperation rate at 3-year follow-up, where reoperation was necessary in glands only greater than 80 mL.[34] Need for retreatment or additional BPH surgery has been reported in 1.9–20% of PUL procedures (see Table 26.2). At the time of TURP, the investigators found that the monofilaments securing the PUL instantly melt and are not an impediment to resection of prostatic tissue.[88] The best way to avoid retreatment is to remove as much adenoma as is safe and possible at the time of endoscopic BPH treatment. In the setting of adenoma regrowth or incomplete treatment, HoLEP has been shown to be safe and effective, with similar improvement in flow rates, PVRs, and symptom scores in men undergoing primary treatment, and just slightly higher rates of clot retention (4.7% vs 1.8%, p = 0.01) and urethral stricture (3.3% vs 1.5%, p = 0.043) in those undergoing retreatment.[80]

MISCELLANEOUS

PUL is an endoscopic treatment for BPH that places permanent implants into the prostate to retract the lateral lobes and expand the urethral lumen. One series reported a 2.1% rate of implant encrustation when the device was inadvertently delivered such that a portion of it was exposed inside

the bladder.[64] Unrecognized this could result in bladder stones, recurrent UTIs, hematuria, and LUTS. To avoid this complication, the surgeon must place the implant no closer than 1 cm to the bladder neck and ensure appropriate angulation.[64] At the end of the procedure the bladder is inspected to assess for exposed implants, and if found they can be removed with endoscopic forceps.

Conclusions

Many minimally invasive endoscopic treatment options exist for BPH. Fortunately, major complications are rare. More common minor complications such as UTI and perioperative bleeding can be minimized with appropriate preoperative workup and management of medications. Postoperative complications such as undesirable retrograde ejaculation can be avoided in many cases with appropriate procedure selection. Most complications can be managed conservatively, though others, including clot retention, urethral stricture, and urinary incontinence, may require further operative intervention to alleviate.

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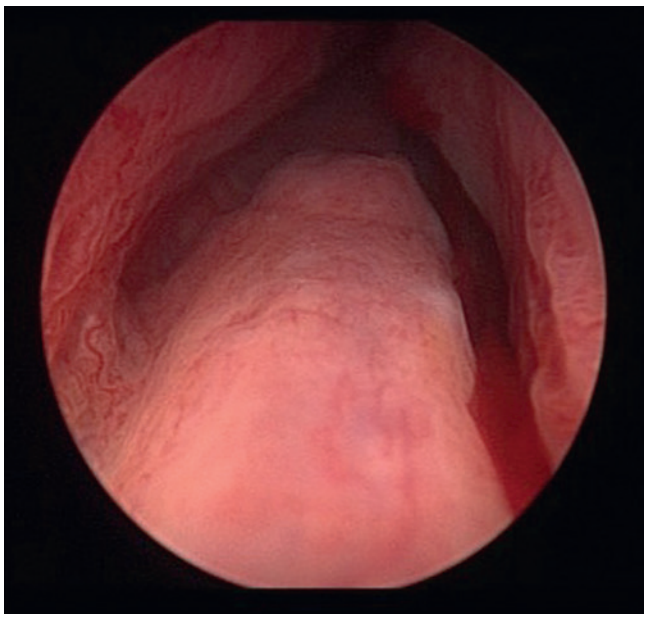
Chapter 26 Questions

1. Which transurethral BPH procedure has the lowest rate of retrograde ejaculation?
   a. Transurethral resection of the prostate
   b. Transurethral incision of the prostate
   c. Photovaporization of the prostate
   d. Holmium laser enucleation of the prostate
   e. Prostatic urethral lift

2. Which of the following does NOT decrease the risk of postoperative urethral stricture following endoscopic BPH surgery?
   a. Smaller resectoscope caliber
   b. Use of monopolar instead of bipolar energy for TURP
   c. Suprapubic tube insertion instead of indwelling urethral catheter postoperatively
   d. Atraumatic insertion of the resectoscope
   e. Larger prostate size

3. Which is NOT a risk factor associated with increased risk of bleeding at the time of transurethral BPH surgery?
   a. Patient age
   b. Prostate size
   c. Longer operative time
   d. Surgical approach
   e. Anticoagulation

4. If treatment of BPH is carried distal to this structure the patient is at increased risk of this complication (Case Fig. 26.1):
   a. Urethral stricture
   b. Rectal injury
   c. Bladder neck contracture
   d. Stress urinary incontinence
   e. Urge urinary incontinence



Case Figure 26.1

5. Where in the urethra is the most common place to develop a urethral stricture following transurethral BPH surgery?
   a. Fossa navicularis
   b. Penile urethra
   c. Bulbar urethra
   d. Membranous urethra
   e. Prostatic urethra

6. Which of the following is NOT associated with TUR syndrome?
   a. Hypertension
   b. Cerebral edema
   c. Blurred vision
   d. Confusion
   e. Seizures

7. All of the following can be done at the time of transurethral BPH surgery when a smaller meatus is encountered to reduce the rate of postoperative meatal stenosis, EXCEPT:
   a. Meatal dilation with sounds
   b. Meatal balloon dilation
   c. Use a smaller resectoscope
   d. Meatotomy
   e. Steroid cream

8. Which factor is NOT associated with increased risk of morcellator injury to the bladder?
   a. Obesity
   b. Smaller bladder size
   c. Experience level
   d. Poor visualization
   e. Inadequate anesthesia and patient movement during surgery

9. Which of the following is NOT part of the treatment algorithm for TUR syndrome?
   a. Hypertonic saline
   b. Hemodialysis
   c. Nephrology consultation
   d. Colloid intravenous fluids
   e. Loop diuretic

10. Which measure is NOT recommended by the AUA guidelines committee to decrease the risk of bleeding at the time of endoscopic BPH treatment?
    a. Hold anticoagulants prior to surgery if medically safe
    b. Send a coagulation panel prior to surgery
    c. Start the patient on finasteride prior to BPH surgery
    d. Check the platelet count
    e. Treatment of preoperative urine culture with antibiotics

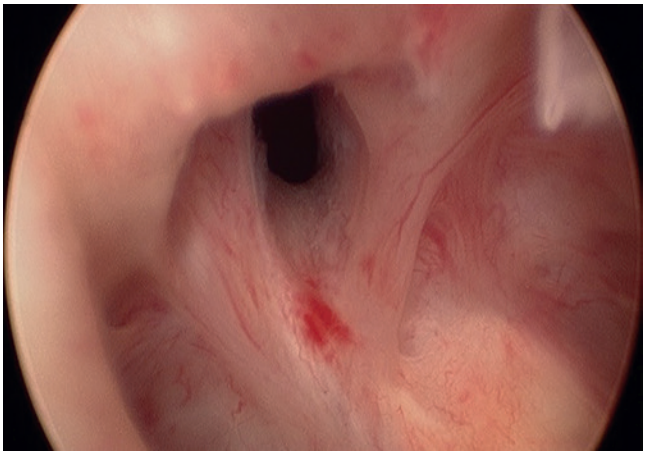
Case Studies

CASE 1

A 68-year-old male underwent TURP 8 months ago. He had an excellent stream initially postoperatively. However, he

now reports having a weak stream and sensation of incomplete emptying. His PVR is elevated from 10 mL at his 2-month postoperative visit to 215 mL and his maximum urinary flow is now 5 mL/s, which is down from 23 mL/s. His American Urological Association Symptom Index (AUASI) is 21, up from 5. His urine dip today is negative for leukocyte esterase or nitrite and has five red blood cells.

1. What is your next step?
   a. Reassure the patient that this is normal and continue routine follow-up
   b. Treat him with a course of antibiotics and recheck his symptoms, urinary flow, and PVR in 1 month
   c. Obtain an abdominal US
   d. Perform cystoscopy
   e. Send urine for cytology



Case Figure 26.2 (Image courtesy of Dr. Douglas F. Milam.)

2. You perform cystoscopy and you see this (Case Fig. 26.2). What is your diagnosis?
   a. Meatal stenosis
   b. Prostate cancer
   c. Urethral stricture
   d. Recurrent BPH
   e. Bladder neck contracture

CASE 2

A 71-year-old male with multiple medical comorbidities, including coronary artery disease with prior coronary stents, lumbar disc disease with history of laminectomy, and symptomatic BPH, desires HoLEP. He has a 170-mL prostate on transrectal ultrasound measurement. A cystoscopy done prior to HoLEP was significant for trilobar prostatic hypertrophy and a trabeculated, small bladder. Video urodynamics had been performed given his history of laminectomy and showed bladder outlet obstruction with good detrusor function, a maximum urinary flow of 7.6 mL/second after voiding 158 mL, and a bladder capacity of 195 mL. He is cleared by his cardiologist to undergo HoLEP but must remain on aspirin 81 mg daily through the procedure. The enucleation part of the procedure is uncomplicated except for some diffuse oozing likely related to antiplatelet therapy. The morcellation portion of the procedure is more challenging. Anesthesia notes that they are having trouble ventilating the patient. The patient is normotensive and develops bradycardia.

1. What are you most concerned is going on?
   a. TUR syndrome
   b. Perforation of the prostatic capsule
   c. Extraperitoneal bladder injury
   d. Intraperitoneal bladder injury
   e. Significant blood loss and symptomatic anemia

2. Which of the following is NOT a risk factor for bladder injury during morcellation of prostatic adenoma?
   a. Small capacity bladder
   b. Poor visualization
   c. Inadequate anesthesia
   d. Obesity
   e. Surgeon experience

3. Which of the following would NOT have decreased the risk of bladder injury in this patient?
   a. Medical management instead of surgery for BPH
   b. Pause morcellation and use the laser to improve hemostasis
   c. Abort morcellation and extract the enucleated tissue via a cystostomy
   d. Perform staged morcellation at which time there will be less bleeding and the tissue will be softer and easier to morcellate
   e. Switch from gravity to pressurized irrigation

Answers

1. **e.** Prostatic urethral lift has the lowest rate of retrograde ejaculation (Case Table 26.1).
2. **b.** A meta-analysis compared mTURP and bTURP and did not find any association between energy type and postoperative urethral stricture.
3. **a.** All factors except age have been associated with increased risk of bleeding.
4. **d.** This structure is the verumontanum and the marker for the urethral sphincter. Resection, enucleation, and vaporization distal to this structure risk injury to the sphincter and stress urinary incontinence.
5. **c.** Most series of endoscopic BPH treatment describe urethral stricture predominantly occurring in the bulbar urethra.
6. **a.** Cerebral edema, blurred vision, confusion, and seizures are all associated with TUR syndrome.
7. **e.** Steroid cream is not a treatment option for intraoperative meatal narrowing or stenosis.
8. **a.** Smaller bladder size, surgeon experience, inadequate visualization, and patient movement are all risk factors for bladder injury during morcellation.
9. **d.** Hypertonic saline, loop diuretics, hemodialysis, and nephrology consultation are measures that may be required to manage TUR syndrome. Colloid intravenous fluids are not used to treat this complication.
10. **c.** Per the AUA guidelines, insufficient evidence exists to recommend the use of 5α-reductase inhibitors to decrease blood loss at the time of endoscopic BPH surgery.

Case Table 26.1 Postoperative Complications[20,32–34,45,51,62–64,77,82,88–91,94,97–174]

	Urinary Tract Infection	Urethral Stricture	Bladder Neck Contracture	Stress Incontinence	Retrograde Ejaculation	Erectile Function		Retreatment
						Worse	Better	
mTURP	2–13.5%	1.1–10%	1.1–12%	1.1–2.2%	57–86%	28%	23%	0–4%
bTURP	0–10.5%	0.8–2%	0–6.6%	0–2.5%	4.5–66.6%	2.2–17%	10.1–28.2%	0–9.4%
HoLEP	0–3.2%	1.7–4.1%	0.4–3.9%	0.7–1.7%	74–78%	11–12%	3–7%	0–1.4%
PVP	0–17%	0–5.1%	0–7.4%	0.8%	49.9%	10%	20%	4.3–11%
BVP	2.4–10%	0–6.8%	0–8%	0–11.7%	59.2–82%	12–13%	nwd	0–43%
TUIP	0–9%	2.4–21.5%	0–2.1%	0–11%	0–35%	0–6.25%	12.5%	4–34.8%
TUMT	0–33%	0–2%	0%	0%	0–22.2%	0–9%	0–15.2%	2.2–32%
TUNA	4–14%	0–1.5%	nwd	0–1.5%	0–15%	0–3%	nwd	9.75–31%
PUL	2.9–12.12%	0%	0%	0%	0%	0%	nwd	1.9–20%

bTURP, bipolar TURP; BVP, bipolar vaporization of the prostate; HoLEP, Holmium laser enucleation of the prostate; mTURP, monopolar TURP; nwd, not well described; PUL, prostatic urethral lift; PVP, photoselective vaporization of the prostate; TUIP, transurethral incision of the prostate; TUMT, transurethral microwave therapy; TUNA, transurethral needle ablation

CASE 1

1. **d.** Based on history, urinary flow, and PVR, this patient sounds like he has developed a recurrent bladder outlet obstruction.
2. **e.** This patient has a bladder neck contracture (BNC). This can be treated with incision of the BNC in the operating room.

CASE 2

1. **d.** The patient is unlikely to be symptomatic from blood loss given normal BP and lack of tachycardia. Additionally, blood loss would likely not cause difficulty with ventilation. Given the use of normal saline irrigant at the time of HoLEP, this patient is at low risk to develop TUR syndrome. Perforation of the prostatic capsule and an extraperitoneal bladder injury would not illicit this response. However, an intraperitoneal bladder injury would result in irrigant filling the peritoneal cavity, causing increased abdominal pressure and cephalad shift of the diaphragm, limiting tidal volume. Peritoneal stretch from the intraabdominal accumulation of fluid can cause a vasovagal type response and the patient can become bradycardic.
2. **d.** No study or anecdotal experience has reported an increased risk of bladder injury at the time of morcellation in obese patients.
3. **e.** If no surgery is performed (a) then no bladder injury will occur in this patient with a small capacity bladder and large prostate, who is on antiplatelet therapy and at high risk for complications. Improving hemostasis and visualization will decrease the risk of complications related to the morcellator (b). If the bladder is too small to safely morcellate this large enucleated adenoma, then open cystotomy should be pursued (c). Anecdotally, some have reported staging morcellation when the tissue was difficult to morcellate secondary to visibility or just tissue quality. By staging the procedure, hemostasis should improve and the tissue will be softer and easier to morcellate (d). The irrigant inflow into the resectoscope should never be placed on pressure (e). If anything this may increase the risk of bladder injury/rupture as the outflow will not be able to keep up with the amount of fluid going into the bladder.

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27 Complications of Ureteroscopic Surgery

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CHAPTER OUTLINE

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Cardiopulmonary Complications
Other Complications
Late Postoperative Complications
Ureteral Stricture
Retained and Encrusted Ureteral Stents
Conclusions
Chapter 27 Questions and Answers

KEY POINTS

1. Complications of ureteroscopy (URS) are rare.
2. Prevention of complications is the best management.
3. Appropriate patient selection, case preparation, and technique will help to minimize the potential for complications.
4. Always bypass the level of obstruction and establish access to the upper urinary tract with a wire prior to addressing any pathology.
5. Always visualize the actions of your instruments and energy sources, and never force the scope or instrument.
6. If a ureteral injury is suspected, then it is acceptable to abort the procedure, place a ureteral stent, and then return for a second session at a later date.
7. Postoperative complications are often minor and can be managed conservatively.

Introduction

Endoscopic surgery for the diagnosis and treatment of disorders of the upper urinary tract is an important minimally invasive tool in the urologists' armamentarium. Since 1929, when Young and McKay[1] documented the use of a cystoscope to perform a ureteropyeloscopy in a child, and with Marshall's first use of a flexible passively deflecting fiberoptic ureteroscope in 1964,[2] ureteroscopy (URS) has continued to progress.

Contemporary indications for URS now include the evaluation and treatment of many conditions of the upper urinary tract including ureteral and renal stone disease, strictures of the ureter, ureteropelvic junction (UPJ) obstruction, intrarenal strictures or calyceal diverticulum, and select upper urinary tract urothelial cell carcinoma (UCC).[3–6] Even with the greatly increased range of indications for URS, the rate of complications has steadily decreased. This change is partly the result of technologic advances such as the development of smaller ureteroscopes, improvements in energy sources with the holmium laser, and the use of smaller endoscopic tools such as guidewires, access sheaths, graspers, and baskets.[3–5] In addition, the skill level of urologists has significantly improved in part because URSs comprise index cases for resident education within the United States.[3]

Despite the now routine use of URS, complications do still occur. In an analysis for the Clinical Research Office of the

Endourological Society (CROES) URS Global Study Group, the observed stone-free rate in 11,885 patients was 85.6% with a very low overall postoperative complication rate of 3.5%, with the most common complication being fever (1.8%).[4] It should be noted that the majority of the complications described in the literature are based on analyses from renal and ureteral stone surgery. Nevertheless, the information can and should be applied to all cases where URS is used. To prevent complications, the best management remains appropriate case preparation with proper selection of the patient, technique, and postoperative care. In this chapter, we discuss the indications for URS, describe the techniques used to perform URS to prevent complications, and identify the possible intraoperative and postoperative complications with strategies to successfully recognize and manage them.

Patient Selection

RENAL AND URETERAL STONES

URS has become the de facto gold standard for the treatment of stones at all locations within the ureter.[5–7] In the kidney, stones up to an aggregate size of 2.0 cm have become routine indications for URS, especially in the lower pole.[7] Larger renal stones may also be addressed with URS but have lower stone-free rates, often require more than one session, and should therefore typically be reserved for percutaneous nephrolithotomy.[7–9]

UPPER URINARY TRACT STRICTURES

Strictures in the ureter, at the UPJ, and intrarenal abnormalities like a calyceal diverticulum are also amenable to URS in selected cases. In the ureter, endoscopic management of strictures is generally limited to those that are nonischemic, nonradiation induced, benign, less than 1.5 cm in length, with minimal ipsilateral hydronephrosis, good renal function, and without prior failed endoscopic attempts.[10] Similarly, for UPJ obstruction, endopyelotomy can be successful for strictures less than 2 cm in length, in the absence of ipsilateral severe hydronephrosis, ipsilateral renal function greater than 25%, and without a crossing accessory renal artery, which is an absolute contraindication.[11] It is also particularly effective as a salvage option following recurrence after an open or laparoscopic repair.[11] Last select intrarenal abnormalities like calyceal diverticulum can be addressed with URS, especially when located in an anterior calyx in the upper or midpole with or without a small associated stone.[12]

UPPER URINARY TRACT UROTHELIAL CARCINOMA

In the management of upper urinary tract UCC, URS is an important modality for both diagnosis and treatment. A diagnostic biopsy can be performed with URS, which is important for determining tumor grade and in treatment planning, especially for those patients with a solitary kidney or considering renal-sparing management.[13] URS ablation of the tumor is an acceptable elective treatment option for patients if the tumor burden can be successfully treated endoscopically and provided they meet strict criteria such as unifocal disease or small volume multifocal disease, small tumor size, low-grade histology on biopsy, noninvasive imaging characteristics, and the ability of the patient to submit to close postoperative surveillance.[13]

Contraindications

As described, appropriate patient selection for each indication is critical to successful treatment but also to prevent complications. Once the patient is appropriately selected for URS, the only absolute contraindication to proceeding is active, untreated infection.[6,7] Therefore, prior to URS all patients must undergo at least a urinalysis with microscopy, but preferably a urine culture.[6–9,14] If the urinalysis suggests infection, or the patient has a culture-proven urinary tract infection, then this must be treated prior to endoscopy.[6,7]

A relative contraindication is an uncorrected bleeding diathesis or ongoing anticoagulation therapy, which cannot be safely discontinued.[7] Despite this, it is still possible to perform URS in these situations, as long as the risks and benefits are clearly discussed with the patient and the medical team prior to proceeding.

Preparation

PREOPERATIVE ASSESSMENT

As with any surgical intervention, appropriate careful preparation is mandatory. In the anticipation of URS, the first step in patient preparation is a history and physical exam. A biochemical evaluation with serum and urine laboratory tests may also be carried out, and as stated previously, a urinalysis or a urine culture is the minimum standard.

Once this is completed, then depending on the pathology to be evaluated or treated, it is often necessary to proceed with an imaging study. For patients suspected of having nephrolithiasis, a noncontrast CT (NCCT) is the recommended first-line imaging modality for an adult nonpregnant patient.[15] However, a renal bladder ultrasound (US) may be an alternative with an NCCT reserved if a stone is suspected in the setting of acute flank pain.[14] For a patient with a ureteral stricture or UPJ obstruction, then a contrast-enhanced CT with delayed, excretory phase imaging (CT urography) to opacify the urinary tract is recommended. This is particularly important for the diagnosis of an upper urinary tract UCC, where CT urography is the recommended first-line imaging modality.[13,16,17] Alternative imaging strategies include MR urography if a patient has an absolute or relative contraindication to a CT, such as with an iodinated contrast allergy.[13,16]

After the diagnosis is made based on history, physical exam, laboratory tests, and imaging studies, then a discussion regarding the appropriateness of URS in the context of the patient's pathology, comorbidities, and provider's skill with URS should be conducted. If URS is selected, then depending on local or regional practice patterns, a preoperative medical evaluation for fitness for anesthesia can be performed.

PERIOPERATIVE PREPARATION

Once in the operating room, but prior to the start of the procedure, appropriate antimicrobial prophylaxis is necessary. A single preoperative dose[7,18] or duration of less than 24 hours is sufficient.[19] The antibiotic should be tailored to preoperative cultures, local resistance patterns, or based on guideline recommendations.[8,19] The timing of administration relative to scope insertion/incision should reflect the pharmacokinetics of the agent selected, which is particularly important for the fluoroquinolones that need to be given 120 minutes prior to incision (as opposed to 60 minutes for most other drugs).[19]

Prophylaxis to prevent thromboembolic events is an important consideration for all surgical patients. In the recent CROES URS Global Study Group, the rate of thromboembolic events was 0.02%.[4] This is an exceedingly rare complication and, therefore, the recommendation is against pharmacotherapy or mechanical prophylaxis, other than early ambulation for patients at very low risk.[20] However, individual patient factors should be taken into consideration, especially if the risk is high, and then pharmacotherapy or mechanical prophylaxis should be strongly considered.[20] It should be noted that despite these recommendations intermittent pneumatic compression is often still used in routine clinical practice.

Appropriate patient positioning is a vital component of the pre-procedure preparation. It provides for both patient and provider comfort. In the majority of instances URS is performed in the dorsal lithotomy position. This position, especially in thin patients and in those undergoing prolonged procedures, can result in neuropraxia, most often to the peroneal nerve, and compartment syndrome, which can lead to rhabdomyolysis.[21,22] Therefore it is important that the patient is appropriately positioned with all pressure points padded, the joints not hyperextended, and adequate perfusion is permitted and maintained to the extremities.[21] Of course, there is no substitute for close clinical monitoring during prolonged cases, especially in those patients at risk.[21]

Last appropriate preparation does not rest solely with the urologist. A coordinated effort is required from all members of the operating room team. Formal preprocedural briefings are becoming routine and have been demonstrated to improve inter-team collaboration,[23] prevent complications, and enhance patient outcomes. Furthermore, centers with a high case volume for URS have increased stone-free rates with decreased retreatment, readmission, and complication rates.[24] This is likely a surrogate for the presence of integrated, coordinated processes surrounding the preoperative, intraoperative, and postoperative care of patients after URS.

Technique of Upper Urinary Tract Endoscopy

CYSTOSCOPY AND INITIAL UPPER URINARY TRACT ACCESS

The initial step of upper urinary tract endoscopy is to perform a proper cystoscopy. This allows for examination of the bladder for concomitant pathology. Once the cystoscopy is complete and no lower urinary tract intervention is deemed necessary, then access to the upper urinary tract may be performed. This starts with identification and intubation of the appropriate ureteral orifice.

This step is most often performed with a guidewire. There are several available on the market of varying diameters and several with a hybrid technology. We prefer to use a hybrid 0.038″ straight Sensor PTFE-nitinol guidewire with hydrophilic tip. We feel that this hybrid wire combines the flexible, delicate tip of a nitinol hydrophilic wire, which is useful for bypassing points of obstruction, with the security and strength of a nitinol core PTFE-coated wire for instrument passage. Thus, it has the theoretical advantage of preventing the use of multiple different wire types.

NEGOTIATING THE OBSTRUCTION

The wire is then advanced under fluoroscopic guidance up to the point of obstruction or, if possible, passed into the renal pelvis (Fig. 27.1). If resistance is met during advancement of the wire, then a 5Fr open-ended ureteral catheter can be placed over the wire up to the point of resistance. The wire can then be removed. A retrograde pyelogram can be performed through the catheter to outline the ureter and collecting system in order to identify the area of concern (Fig. 27.2). If there is complete obstruction on the retrograde pyelogram, then an alternative access to the upper urinary tract may be necessary, such as a percutaneous access.

However, if this is not the case, then there are several strategies to negotiate the wire past the level of obstruction. If the issue is kinking of the wire, then the 5Fr open-ended ureteral catheter can be left in place to provide additional support. If, however, the wire continues to kink or coil, then the next step is to try a hydrophilic guidewire, which has the nitinol core of the guidewire but with a lubricated coating allowing for ease of passage and flexibility. These can be either straight or angled. By using these wires, it is often possible to bypass areas of narrowing or tortuosity not amenable with the standard or hybrid guidewire. It should be kept in mind that serial unsuccessful attempts at wire passage across an area of obstruction can lead to further injury, complicating future management. Therefore, if this is encountered, then it is reasonable to abort the procedure and consider alternative access to the upper urinary tract or decompression with percutaneous access.

MAINTAINING ACCESS

If a hydrophilic guidewire is used and placed into the collecting system, then this wire should be exchanged for the stiffer guidewire prior to instrument or URS placement. This can be done with a 5Fr open-ended ureteral catheter placed above the level of obstruction under fluoroscopic guidance. As stated previously, the hydrophilic guidewire has lubricity and is flexible, making it prone to migrating if used for manipulation. Once a guidewire is situated in the kidney, above the level of obstruction, then it is possible to proceed with endoscopy. However, if turbid or purulent urine is encountered at this, or any point, then it is mandatory to

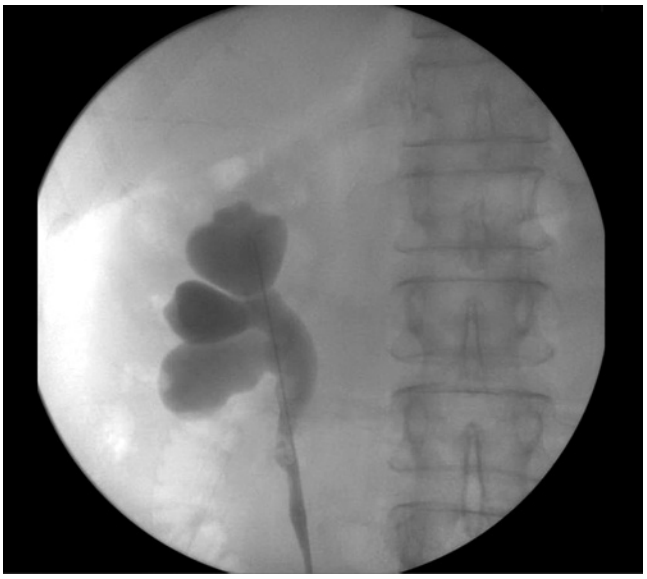


Figure 27.1 A large proximal ureteral stone is visualized with proximal moderate hydronephrosis. It was possible for a guidewire to be placed past the stone into the renal pelvis. To prevent complications, the level of obstruction should always be passed with a wire prior to advancing the ureteroscope.

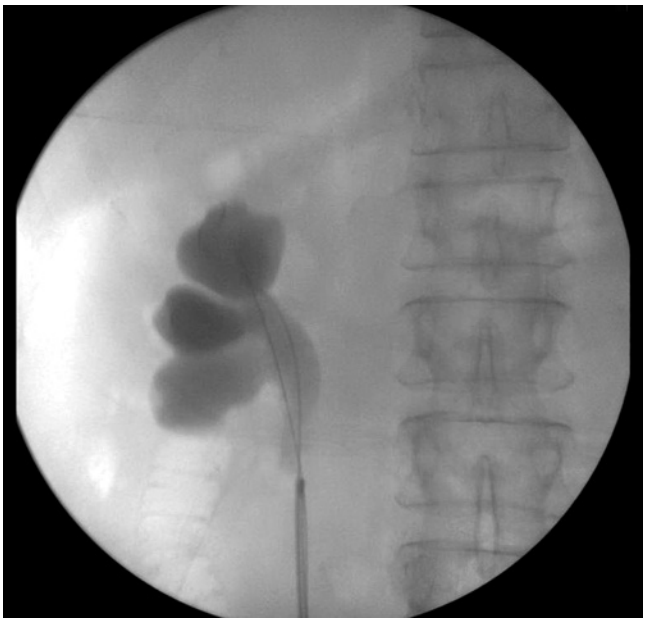


Figure 27.3 Working and safety guidewires were placed into the renal pelvis. Over the working wire, the ureteroscope is advanced into the collecting system. The safety wire remains in place. If complications do occur, a safety wire will provide persistent access to the renal collecting system for ureteral stent placement.

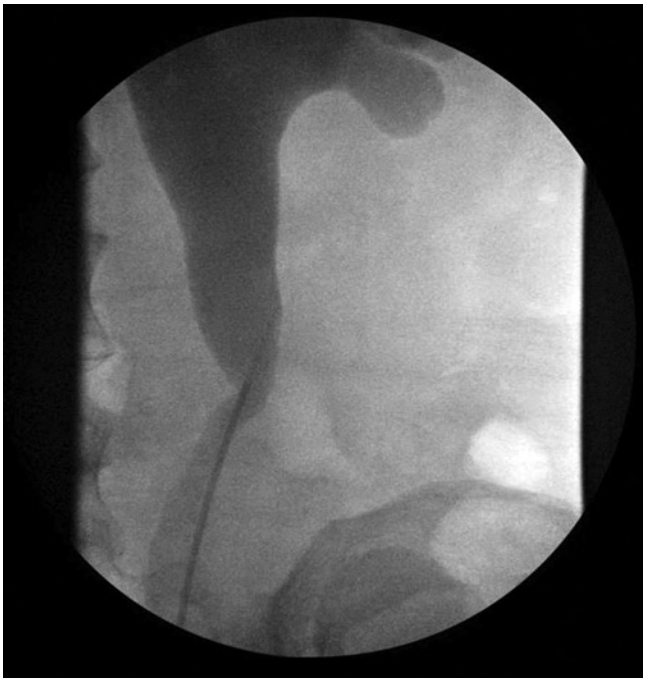


Figure 27.2 The placement of a wire in the renal pelvis was attempted, but resistance was met in the mid- to proximal ureter. The wire was exchanged for a 5Fr open-ended ureteral catheter. A retrograde pyelogram was performed, which demonstrated moderate hydroureter with a kink in the mid- to proximal ureter and proximal moderate-to-severe hydronephrosis. Once the anatomy was outlined, the 5Fr open-ended ureteral catheter was exchanged for a guidewire, and this kink was bypassed with placement of the wire in the renal pelvis. To prevent complications, the ureteral anatomy should be defined with a retrograde pyelogram, if resistance is met during initial wire placement.

abort the remaining procedure, place a ureteral stent for decompression, and then treat accordingly with appropriate antibiotics.[8,9]

Although a single wire may suffice, it is often prudent to place a second, safety wire to ensure access to the collecting system at all times, especially in the event of ureteral injury (Fig. 27.3). This is often done using a dual-lumen ureteral access catheter or an 8/10Fr dilator/sheath set. This is placed over the original, working wire into the distal ureter, and then a second, safety wire is placed through the device into the collecting system under fluoroscopic guidance. Both devices are also useful for gently dilating the ureteral orifice and intramural ureter to later accommodate the URS.

ENTRY OF THE URETEROSCOPE

If a rigid URS is required, which we typically limit to the distal one-third of the ureter below the crossing of the iliac vessels in men and the mid- to proximal ureter in women, then placement of a second wire can be done under direct visualization. A nice strategy is to place the second wire through the scope as the scope is advanced up the ureter, thereby "railroading" the scope between the two wires. Each wire acts to straighten and stent open the ureter as the scope passes by for improved visualization.

If a flexible URS is used, then either an instrument, such as a ureteral access sheath, or the URS itself can be advanced over the wire. This is usually done under fluoroscopic guidance. We prefer to use a ureteral access sheath for larger stone burdens (>1.0–1.5 cm), as they have demonstrated improved entry/reentry of the scope, decreased intrarenal pressures, as well as a suggestion of improved clinical

outcomes with a lower stone-free rate and reduced infectious complications but without increasing the rate of ureteral injury.[25,26]

At any point, if the instrument or scope cannot be advanced due to a narrowed ureter, then the options include serial or balloon dilation of the ureter or placement of a ureteral stent with a plan to return for a second attempt at ureteroscopy.[27] Typically, the distal ureter or a short segment of the ureter is dilated, only up to 12Fr. In our practice, we advocate for placement of a ureteral stent (Fig. 27.4) over ureteral dilation. This will allow for passive dilation of the ureter. A repeat attempt at access in a delayed setting is successful in the vast majority of cases.[28] We do not recommend using serial or balloon dilators, as we feel this is associated with a relatively high complication rate,[29] although it does involve the need for a second surgery.

ENDOSCOPY

Once the scope reaches the point of the pathology (stone, stricture, or tumor), then work can begin. The actual procedure will depend on the problem to be addressed. However, irrigation is a key component of all upper urinary tract procedures. Proper irrigation will allow for maximal visualization to facilitate safe and effective performance of the procedure. Saline should always be used for irrigation with URS due to the risk of hyponatremia with hypotonic solution.[9] There are advocates for both passive and active irrigation systems. Active (hand pump) irrigation systems reportedly have an increased risk of stone migration[30] with a suggestion of increased risk of pyelovenous and pyelolymphatic backflow, which can lead to infectious complications. We prefer to use a passive irrigation system with pressure bags. However, we acknowledge that for challenging cases with poor visualization it may be necessary to use an additional active irrigation mechanism to improve the field of view.

Intraoperative Complications

The overall rate of intraoperative complications is very low (Table 27.1). In the contemporary CROES multicenter, multinational clinical registry of URS, the rate was 5.5% in over 11,000 patients.[4] All of these were related to the ureter.



Figure 27.4 A wire was placed into the collecting system. The advancement of the ureteroscope up the ureter over the wire was attempted, but it could not be advanced past the distal ureter. The wire was exchanged for a 5Fr open-ended ureteral catheter and a retrograde pyelogram was performed. This demonstrated a very narrow caliber ureter, which was only approximately 5Fr in diameter. Therefore it would not accommodate the ureteroscope. A ureteral stent was placed for passive dilation of the ureter with plans to return for a delayed ureteroscopy.

Table 27.1 Intraoperative Complications of Ureteroscopic Surgery and Management

Complication	Risk Factor[a]	Etiology	Rate[b]	Management
Ureteral bleeding	Multiple ureteral locations Low-volume center	Dilation Misfired energy Mucosal injury	1.4%	Observation Ureteral stent
Ureteral erosion or false passage	Unknown	Wire placement Scope manipulation Misfired energy Instrument deployment Stone removal	Unknown	Observation Ureteral stent
Ureteral perforation	Midureteral location Low-volume center	Wire placement Scope manipulation Misfired energy Instrument deployment Stone removal	1.0%	Ureteral stent
Ureteral intussusception or avulsion	Low-volume center	Entrapped stone removed with excessive force	0.1%	Nephrostomy tube Delayed repair

([a]Adapted from Perez Castro E, Osther PJ, Jinga V, et al. Differences in ureteroscopic stone treatment and outcomes for distal, mid-, proximal, or multiple ureteral locations: the Clinical Research Office of the Endourological Society Ureteroscopy Global Study. Eur Urol. 2014 Jul;66(1):102-9; and Kandasami SV, Mamoulakis C, El-Nahas AR, et al. Impact of case volume on outcomes of ureteroscopy for ureteral stones: the Clinical Research Office of the Endourological Society Ureteroscopy Global Study. Eur Urol. 2014 Dec;66(6):1046-51.)

([b]Adapted from de la Rosette J, Denstedt J, Geavlete P, et al. The Clinical Research Office of the Endourological Society Ureteroscopy Global Study: indications, complications, and outcomes in 11,885 patients. J Endourol. 2014 Feb;28(2):131-9.)

Several factors were also shown to modify the risk of intraoperative complications.[5,24,26] However, preoperative ureteral stent placement was not one of them. In fact, there was no difference in intraoperative complications with or without pretreatment ureteral stent placement in either renal or ureteral stones.[31]

A grading system developed by the American Association for the Surgery of Trauma exists for traumatic injuries.[32] This ranges from contusion (grade I) to complete transection with extensive devitalization (grade V).[32] However, this is not applicable to iatrogenic injuries. Instead, a specific classification system was developed for injury from URS.[33] In this scale, damage to the ureter ranges from wall petechiae (grade 0) to mucosal erosion (grade 1) to perforation with or without advential preservation (grade 2 and 3) to total avulsion (grade 4) (Fig. 27.5).[33] Although this continuum when divided as either low grade (grade 0 and 1) or high grade (grade 2, 3, and 4) is useful as a framework with which to discuss iatrogenic ureteral injuries from URS, it is rarely used clinically.

URETERAL BLEEDING

Bleeding was the second most common complication in the CROES registry at only 1.4%.[4] However, it was more common when stones were treated in multiple locations (2.5%) as compared to only a single location in the proximal (0.9%), mid- (1.3%), or distal (1.3%) ureter.[5] Similarly, case volume also influenced the rate. Low-volume centers had more than twice the rate as high-volume centers (2.5% vs 0.9%).[24] Minor bleeding can occur during ureteral dilation, due to misfired energy from a laser, or at sites of pathology, such as along the mucosa of an impacted stone or from a papillary urothelial tumor. Additionally, wires advanced too far can pierce the collecting system and enter the renal parenchyma, leading to minor bleeding. The rate of

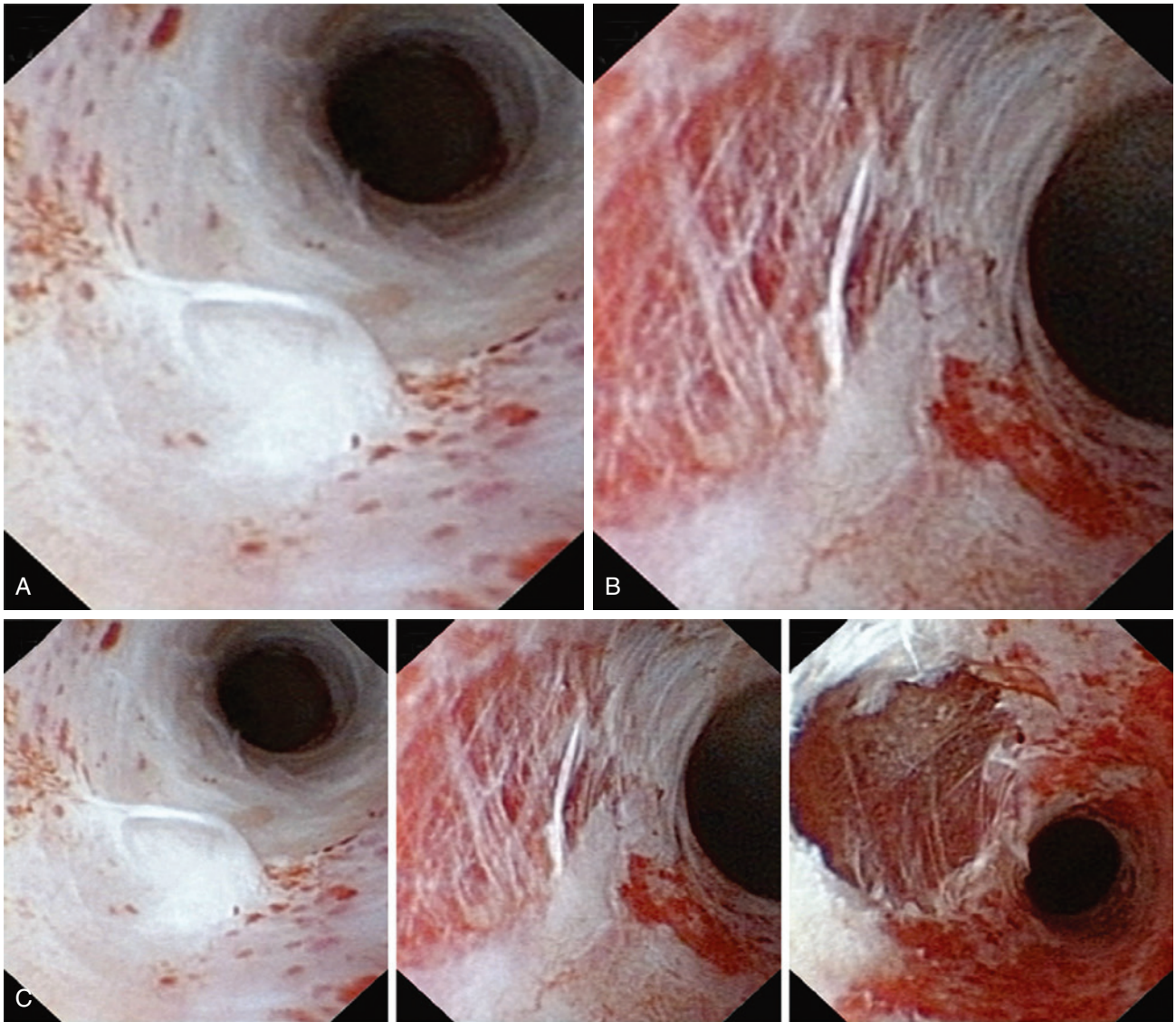


Figure 27.5 Part A demonstrates ureteral mucosal erosion (grade 1). Part B shows ureteral perforation with adventitial preservation (grade 2). Part C displays ureteral perforation without adventitial preservation where periureteral fat is visible (grade 3). Prompt recognition of these injuries is key with ureteral stent placement to facilitate healing. (Adapted from Traxer O, Thomas A. Prospective evaluation and classification of ureteral wall injuries resulting from insertion of a ureteral access sheath during retrograde intrarenal surgery. J Urol. 2013 Feb;189(2):580-4.)

subcapsular hematoma is estimated at 0.36–0.4%.[34,35] This minor bleeding is usually self-limited. However, it can reduce visibility if it enters the collecting system, and active irrigation may be necessary for a short period of time. More extensive bleeding is very rare, although it can occur, especially from a large papillary urothelial tumor, or following endopyelotomy for a UPJ obstruction with rates as high as 8–9%.[36,37] Rare causes of massive ureteral bleeding include endometriosis and ureteroarterial fistulas.[38] If bleeding is severe and persistent or visualization is poor, then it is prudent to abort the procedure and place a ureteral stent. This is usually sufficient to tamponade the bleeding. However, it may be necessary to consider further intervention such as angioembolization[37] or, rarely, nephrectomy in select situations. A blood transfusion after ureteroscopy is very rare, estimated at only 0.2%.[4]

LOW-GRADE URETERAL INJURY

Low-grade ureteral injuries consisting of either a contusion with wall petechiae, a superficial mucosal erosion, or false passage are likely very common during URS. However, the exact incidence is unknown. In a multi-institutional cohort, there were a total of 311 (86.6%) patients who experienced a low-grade ureteral injury after URS with the use of a ureteral access sheath.[33] The reporting of this complication is absent from other studies, particularly the comprehensive CROES URS registry.[4] Nevertheless, as it is commonly encountered in routine clinical practice, recognition and treatment are still important. The mucosal erosion typically occurs during wire placement, scope manipulation, misfired energy, instrument deployment, or stone removal. After the injury, it is still possible to complete the procedure, but extra care must be taken not to convert a mucosal erosion to a perforation. This can best be avoided by moving the action of the procedure away from the site of injury. This is especially true if stone fragmentation is undertaken, as stones displaced outside the ureter are associated with the later development of ureteral strictures.[39] Furthermore, if at all possible, the site of injury should not be crossed repeatedly, as is common practice with basket stone removal. At the conclusion of the procedure, or if there is concern for a worse ureteral injury, then it is reasonable to abort the procedure and place a ureteral stent. The late development of a ureteral stricture after URS is very rare, with a contemporary reported rate of only 0.3%.[4]

HIGH-GRADE URETERAL INJURY

High-grade ureteral injuries, although potentially devastating, are now increasingly rare. These include ureteral perforation, intussusception, and avulsion. As stated previously, perforation involves injury to all layers of the ureter with either the adventitial or the periureteral fat containing the area of damage. The perforation, as with mucosal erosion, can occur with wire placement, scope manipulation, misfired energy, instrument deployment, and stone removal. The current accepted rate of perforation is 1%.[4] It is more common in midureteral locations (1.6%) than in the proximal (1.1%), distal (0.7), or multiple locations (1.1%).[5] Similarly, a low-volume center is associated with an increased rate as compared to a high-volume center (2.3% vs 0.8%, respectively).[24] Surprisingly, the rate was not changed with or without use of a ureteral access sheath (1.2%).[26] Once a perforation is identified, then the procedure should be aborted and a ureteral stent should be placed. The procedure can then usually be accomplished in a delayed fashion after several weeks with ureteral stent drainage. Again, the late development of a ureteral stricture is very rare.[4]

Intussusception is also a rare event where the mucosa telescopes inward, folding in on itself, and separating from the underlying stroma. This is often associated with antegrade or retrograde basket stone removal, where the stone entrapped within the basket is too large to be removed from a narrowed, unaccommodating ureter.[40] The force of removal shears the ureteral mucosa, pulling it inward with the basket. This is one reason why blind basketing is prohibited.[6] The exact incidence of this complication is unknown, as it is likely not reported separately from avulsion.

Ureteral avulsion is the most feared and devastating complication of URS. Thankfully, it is exceedingly rare. It is reported to occur in only 0.1% of cases.[4] The location of treatment (proximal, mid, distal, or multiple locations) does not seem to influence the rate of avulsion.[5] However, case volume does. The rate was over 12 times higher in low- as compared to high-volume centers (0.5% vs 0.04%).[24] Similarly to intussusception, ureteral avulsion typically occurs when a stone too large to be removed is engaged within a basket and then excessive force is used to remove it. During removal, the ureter becomes entrapped, tears from its attachments, and then is externalized with the basket and scope as they are withdrawn. If this is recognized, then the procedure must be aborted immediately. Another possible complication related to intussusception and avulsion is the "scabbard effect," where the proximal scope, which is larger in diameter than the tip, becomes wedged in the narrower distal ureter, resulting in friction and dissociation of the mucosa. This is similarly observed when small stone fragments get trapped along the length of the scope.

For intussusception, avulsion, and the scabbard effect, proper technique is the best prevention. When stone removal is undertaken, the mucosal wall must always be visualized. If resistance is met at any point, then further removal must be aborted. The ureter should then be inspected for integrity. Again, blind basketing without direct visualization should be avoided,[6] and excessive force should never be used. If, however, intussusception or avulsion does occur, then placement of a ureteral stent is likely not possible, nor will it provide for adequate drainage as the ureter is completely devascularized. Therefore, it is prudent to urgently place a nephrostomy tube. Formal open or laparoscopic surgical repair will be required. The type of repair will depend on the location and extent of the injury, comorbid medical conditions, and the experience of the surgeon.[40] The repairs range from simple ureteroneocystotomy to psoas hitch or Boari flap to ileal interposition to autotransplantation or nephrectomy.[40] Therefore we do not advocate for immediate repair but rather a delayed approach for time to adequately discuss the options with the patient.

FAILURE AND CONVERSION

Failure is defined as an inability to access the ureter or stone during initial treatment. Both failure and conversion are

reported as complications in modern series with overall rates of 1.6% and 0.1%, respectively.[4] There is evidence that stone location and procedure volume do influence the rates. Failure is more common in a proximal (2.8%) location than in a mid- (1.9%), distal (0.7%), or at multiple (0.7%) locations.[5,41] Similarly, it is more common in low- as compared to high-volume centers (2.3% vs 1.5%).[24] This was also observed for the rate of conversion (0.4% vs 0.01%).[24] Although both failure and conversion are listed as complications, in certain circumstances they should be viewed as appropriate treatment, especially if further attempts at ureteroscopy would lead to injury.

Instrument Failure

Instrument failure can include any piece of equipment necessary to safely and adequately perform URS. This can be the ancillary equipment such as the operating room table, positioning devices, and fluoroscopy unit; the endoscopic tools such as the laser generation unit, laser fiber, and stone retrieval basket; and the scope itself. However, we will focus only on the endoscopic tools, particularly the stone retrieval basket, and the scope. The exact rate of endoscopic tool failure and/or breakage is not known. It is likely not all that common, but it is important to be familiar with strategies should it occur. Scope durability, however, is well defined and quantifiable, which allows for appropriate planning and preparation.

Stone Retrieval Basket Failure. The stone retrieval baskets used for URS are now miniaturized to 1.9Fr for improved irrigation, tipless to prevent mucosal abrasions, and composed of nitinol, allowing for maximal flexibility without compromising strength.[42] In fact, they are the only basket recommended by current EAU guidelines for stone extraction.[7] Despite their clinical utility, the baskets remain susceptible to damage, especially when laser energy is directly applied.[43] Therefore when a basket is broken, it should be immediately disengaged from the stone. The basket can then be withdrawn into the scope or, if not possible, then carefully withdrawn out of the ureter under direct visualization.[40] It is imperative to always be cognizant of the end of the basket and the damaged or disrupted tine to prevent its catching on the ureter.[40]

The other possible scenario involving a basket is if it is used to grasp a stone larger than the ureter will accommodate for removal. As stated previously, this is the condition where ureteral intussusception or avulsion can occur if excessive force is applied. Typically, the basket will be able to be disengaged from the stone, but sometimes this is not possible. In this case, one strategy is to disassemble the basket. Usually, the external end of the basket housing can be unscrewed (or the basket wire itself cut), which allows the outer sheath of the basket to be removed through the scope while the internal basket wires remain in place. This often increases the opening diameter of the basket wires, facilitating disengagement from the stone. If this occurs, then it can be removed through the scope with the stone left in place.

If this does not disengage the basket from the stone, then two additional strategies are possible. The first is to pass a 200-micron laser fiber through the working channel alongside the dissembled basket. The stone can then be fragmented in situ while engaged within the basket. Once the stone is in pieces less than 2–3 mm, the basket can usually be separated from the stone and removed. When employing this strategy, it is important to know that irrigation through the scope will be minimal and also that maneuverability of the scope must be limited as it is still engaged to the basket and stone. The alternative option is to remove the scope entirely over the disassembled basket and then reinsert it alongside the basket up to the level of the stone.[40] The laser can then be introduced and the stone fragmented, allowing for safe basket removal. In fact, a proprietary basket, termed the "Escape" basket, is a 1.9Fr device specifically designed to engage the stone and then allow passage of a 200-micron laser fiber through the basket to facilitate fragmentation of the stone.[44]

Scope Damage and Durability. Damage to the URS is primarily localized to degradation of the lens/fiber optic bundle, channel perforation, or loss of deflection. In a survey of the four major URS manufacturers (ACMI, Olympus America, Karl Storz, and Richard Wolf) in 2005, repairs to the URS were to the working channel, shaft of the scope, deflection mechanism, and the eyepiece in 52%, 27%, 15%, and 8% of cases, respectively.[45] The mechanism was attributed to the laser in 42% of the cases with damage to the working channel, 20% of the cases with damage to the body of the shaft, 20% of the cases with damage to the optical fibers, and 45% of the cases with damage to the deflection mechanism.[45] Other top causes for the damage at each site included instrument insertion/extraction, extreme bending, sterilization, and storage.[45]

By understanding the common mechanisms of damage to the URS, strategies aimed at preventing or mitigating them can be designed and implemented to improve the longevity of each scope. In particular, avoiding firing of the laser in close proximity to the tip of the scope or within the working channel will prevent damage to the fiberoptic bundles and working channel. Similarly, not deploying endoscopic devices when the scope is at extreme degrees of deflection will also preserve the working channel.

Durability represents the number of repairs over the total number of cases performed. In a contemporary series with a modern third-generation fiber-optic URS model (Olympus URF P5), all 643 cases at a single ambulatory surgical center in the United States were examined during a 3-year period (2011–2014).[46] There were 31 repairs performed on the four flexible URSs for an average of 21 procedures between repairs.[46] With the new fourth-generation digital URS there is a suggestion of even superior durability. In a retrospective analysis at a single institution with a single surgeon using a single model of digital URS (Storz Flex-Xc) from 2012–2013, the three scopes were able to be used for 96, 151, and 159 cases, respectively, prior to repair.[47]

Durability varies by scope manufacturer, practice location, surgeon, sterilization technique/team, and case mix. Therefore, it is important to have an understanding of the average durability of your scope. This will allow for proper inventory so that in every case, a clean, functional scope is always available. In our experience, this is best achieved through standardization of staff, processes, and equipment in consultation with manufacturer representatives. The recent introduction of a single-use (disposable) digital

ureteroscope into the market provides an alternative option that eliminates many of the issues related to durability and reprocessing and, thus, may increase the value of the procedure.

Early Postoperative Complications

In the contemporary CROES multicenter, multinational clinical registry of URS, the rate of postoperative complications was 3.5% in over 11,000 patients (Table 27.2).[4] Of these patients, 78% (2.8% of the total population) experienced a low-grade complication (Clavien Grade I or II) and 19% (0.62% of the total population) experienced a high-grade complication (Clavien Grade III, IV, or V).[4] The causes of death in the Clavien V group (five patients, or 0.02% of the total population) were sepsis, pulmonary embolism, cardiac arrest, multisystem organ failure, and fatal arrhythmia.[4]

INFECTIOUS COMPLICATIONS

Fever was the most common immediate postoperative complication, with a rate of 1.8%.[4] Documented urinary tract infection was rare, with a rate of 1.0%, and progression to sepsis was even rarer, with a rate of 0.3%.[4] There was a single documented death related to sepsis.[4]

As infectious complications are common after URS, it is important for the practicing endourologist to know how to prevent, recognize, and treat them. According to guideline recommendations, a preoperative urine microscopy or culture is necessary, and all bacteriuria and UTI should be treated prior to URS.[6,8] Antibiotic prophylaxis is indicated. A single preoperative dose[7,18] or duration of less than 24 hours is sufficient.[19] The antibiotic should be tailored to preoperative cultures, local resistance patterns, or based on guideline recommendations.[19] The timing of administration relative to scope insertion/incision should reflect the pharmacokinetics of the agent selected, which is particularly important for the fluoroquinolones that need to be given 120 minutes prior to incision (as opposed to 60 minutes for most other drugs).[8,19] Despite these guideline recommendations,[7,19] a recent analysis of the CROES URS registry demonstrated no difference in fever or UTI for those patients receiving as compared to those patients not receiving perioperative antimicrobial prophylaxis for both renal (fever: 2.2% vs 2.2%; urinary tract infection: 1.6% vs 1.1%) and ureteral (fever: 1.1% vs 0.5%; urinary tract infection: 0.6% vs 0.4%) stones.[48] The risk factors identified for the development of infectious complications included female gender, Crohn's disease, anticoagulation use, increasing stone burden, and an ASA score greater than II.[48] Although this study does challenge accepted recommendations, we still advocate for a single dose of antimicrobial prophylaxis prior to scope insertion, which is not continued postoperatively.

Of all the infectious complications, sepsis is the most feared, and if it is not recognized early it has a high mortality.[49] Sepsis is a systemic response to probable or documented infection, and severe sepsis is sepsis plus end-organ dysfunction or tissue hypoperfusion.[49] Early recognition is key. Therefore all urologists should be familiar with the evaluation and treatment of sepsis, which can occur during manipulation of an obstructed, infected urinary system. Current guidelines recommend initial fluid resuscitation, bacterial cultures prior to starting antimicrobial therapy, imaging to confirm the potential source of infection, administration of antibiotics within the first hour with activity against all likely pathogens and tissue penetration against

Table 27.2 Early Postoperative Complications: Prevention and Management

Complication	Rate[a]	Prevention	Management
Bleeding	0.4%	Sound endoscopic technique	Observation Ureteral stent
Bladder spasms	0.4%	Avoid ureteral stent placement	Remove ureteral stent Anticholinergics Alpha-blockers
Fever	1.8%	Negative baseline urinalysis or culture Single-dose antimicrobial	Antimicrobials
Urinary tract infection	1.0%	Negative baseline urinalysis or culture Single-dose antimicrobial	Antimicrobials
Sepsis	0.3%	Negative baseline urinalysis or culture Single-dose antimicrobial	Fluid resuscitation Antimicrobials Cultures Imaging Source control
Venous thromboembolic	0.02%	Early ambulation Mechanical or pharmacologic in high-risk patients	Early recognition Anticoagulation
Cerebrovascular	0.02%	Preoperative medical evaluation	Early recognition
Acute myocardial infarction	0.01%	Preoperative medical evaluation	Early recognition
Death	0.02%	Preoperative medical evaluation	Early recognition

([a]Adapted from de la Rosette J, Denstedt J, Geavlete P, et al. The Clinical Research Office of the Endourological Society Ureteroscopy Global Study: indications, complications, and outcomes in 11,885 patients. J Endourol. 2014 Feb;28(2):131-9.)

the likely source, and early (<12 hours) source control.[49] In the setting of URS, if sepsis is recognized, then the procedure should be immediately aborted, cultures obtained, and a ureteral stent or percutaneous nephrostomy placed for immediate decompression.

CARDIOPULMONARY COMPLICATIONS

These are the rarest complications in the immediate postoperative period. In the recent CROES URS Global Study Group, the rates of venous thromboembolic events, cerebrovascular accident/transient ischemic attack, and acute myocardial infarction were 0.02%, 0.02%, and 0.01%, respectively.[4] Although rare, these complications can be devastating. Therefore prevention remains the best strategy. For venous thromboembolic events, guidelines recommend against routine pharmacotherapy or mechanical prophylaxis, other than early ambulation for patients at very low risk.[20] However, individual patient factors should be taken into consideration, especially if the risk is high, and then pharmacotherapy or mechanical prophylaxis should be strongly considered.[20] Despite these recommendations, intermittent pneumatic compression is often still used in routine clinical practice. To prevent cerebrovascular events, it is important to manage patients' risks with optimization of their medical comorbidities in consultation with a primary care physician or cardiologist prior to URS.

OTHER COMPLICATIONS

These include bleeding and bladder spasms. For both, the reported rate is 0.4%.[4] The majority of bleeding is likely clinically insignificant as the need for a blood transfusion after URS is very rare.[4] Bleeding is usually self-limited and, if not, then can often be controlled with a ureteral stent alone. As for bladder spasms, this is likely an under-reported complication. These can originate from the procedure itself but are more commonly associated with the postoperative indwelling ureteral stent. One way to avoid these symptoms is to not place a ureteral stent. According to current guidelines, placement of a ureteral stent is optional after uncomplicated URS.[6,7,9] Despite this recommendation, in the CROES URS registry, over 80% of cases had a ureteral stent inserted.[4] If a ureteral stent is left in place, both alpha-adrenergic antagonists and anticholinergics have demonstrated efficacy in reducing stent-related symptoms, although it is unclear if one is superior to the other or if a combination is beneficial.[50,51]

Late Postoperative Complications

In the contemporary CROES multicenter, multinational clinical registry of URS, the readmission rate within 3 months was 8.4% (Table 27.3).[4] When the reason was identified, it was due to flank pain (1.1%), ureteral stent discomfort (0.9%), and ureteral obstruction (0.5%).[4] The majority of these can be managed conservatively. Ureteral stricture, on the other hand, can be devastating, often requiring formal open or laparoscopic surgical revision. Thankfully, this late complication is very rare, with a reported rate of only 0.3%.[4]

Table 27.3 Late Postoperative Complications: Prevention and Management

Complication	Rate[a]	Prevention	Management
Readmission	8.4%	Sound endoscopic technique	Early recognition variable
Ureteral stricture	0.3%	Sound endoscopic technique	Postoperative imaging Endoscopic dilation or incision Open or laparoscopic repair
Encrusted/ retained ureteral stent	Unknown	Avoid ureteral stent placement Patient counseling Ureteral stent registry	Postoperative imaging Endoscopic removal

([a]Adapted from de la Rosette J, Denstedt J, Geavlete P, Keeley F, Matsuda T, Pearle M, et al. The Clinical Research Office of the Endourological Society Ureteroscopy Global Study: indications, complications, and outcomes in 11,885 patients. J Endourol. 2014 Feb;28(2):131-9.)

URETERAL STRICTURE

Ureteral stricture formation likely results from injury to the mucosa and underlying lamina propria leading to vascular compromise, fibrosis, and ultimately luminal narrowing. The mechanism by which the injury occurs is varied. It can be iatrogenic due to perforation from wire placement, scope manipulation, misfired energy, instrument deployment, or stone removal. It can also be due to the impacted stone itself. In one historical series, there was an observed ureteral stricture rate of 24% in the setting of perforation at the site of an impacted stone.[52] Furthermore, all the stones were impacted for greater than 2 months, suggesting that not only perforation but also duration of impaction was a risk factor for ureteral stricture formation.[52] However, in a more contemporary series, the rate of ureteral stricture formation was significantly lower at only 7.8%. None of the traditional risk factors, including stone size, presence of impaction, duration of impaction, site of impaction, or mucosal injury/perforation was associated with ureteral stricture formation.[53] Furthermore, registry data have demonstrated that ureteral stricture formation is not associated with stone location[5] or the use of a preoperative ureteral stent.[31] Ureteral access sheaths also do not appear to increase overall postoperative complications.[26] Despite these conflicting reports, prevention remains the best solution. Therefore sound endoscopic techniques as previously described always should be followed to prevent injury to the ureter and thus avoid development of a ureteral stricture.

Although rare, detection of a ureteral stricture is important, especially in the setting of silent obstruction. According to current guidelines, postoperative imaging to confirm removal of the stone and resolution of hydronephrosis is recommended.[15] This should be performed first with a renal ultrasound and then subsequent imaging, depending on the modality of treatment and the findings.[15] Although the rate of ureteral stricture formation is rare, and silent obstruction in this setting is even rarer, a recent analysis

demonstrated the possible cost-effectiveness of routine imaging as opposed to imaging only for symptoms following URS.[54] In this analysis, opportunistic imaging only after the development of symptoms resulted in a $130 savings per patient but at the risk of loss of up to two kidneys per 100 patients.[54] Therefore the authors concluded that the minimal cost increase for routine postoperative imaging was justified as it prevented renal unit loss.[54]

After a ureteral stricture is identified, then the type of repair will depend on the location and extent of the injury, comorbid medical conditions, and experience of the surgeon.[40] Endoscopic management of strictures is generally limited to those that are nonischemic, nonradiation induced, benign, less than 1.5 cm in length, with minimal ipsilateral hydronephrosis, good renal function, and without prior failed endoscopic attempts.[10] If endoscopic repair is not an option, then formal open or laparoscopic surgical repair may be required. These repairs include simple ureteroneocystotomy, psoas hitch or Boari flap, ileal interposition, autotransplantation, and rarely nephrectomy.[40]

RETAINED AND ENCRUSTED URETERAL STENTS

The optimal duration a ureteral stent remains indwelling should be the shortest possible period of time that is deemed safe for the patient. Ureteral stents themselves are associated with complications, including irritative voiding symptoms, infection, hematuria, migration, encrustation, obstruction, and renal unit loss.[55] In an early analysis of modern ureteral stents, encrustation occurred in 9.2%, 47.5%, and 76.3% at less than 6 weeks, 6 to 12 weeks, and greater than 12 weeks, respectively.[56] Even in stents that remained in place for less than 3 months, a 30% rate of luminal occlusion was cited, but the incidence of clinical obstruction was noted to be only 4%.[56] Therefore to completely eliminate the risk of stent-related complications, a ureteral stent should not be placed after routine URS, as recommended by current guidelines.[6,7,9] If, however, a ureteral stent is placed, then appropriate patient counseling is necessary to ensure timely follow-up for removal. Additionally, a ureteral stent registry may also be valuable to ensure adequate tracking and provide reminders to staff. Patient noncompliance is a commonly cited risk factor,[55] and these patients should be given extra attention in follow-up.

When a ureteral stent becomes encrusted, removal requires complex, often multiple endoscopic procedures.[55,57,58] However, prior to any removal, it is recommended that the patient undergo a CT scan to document the degree of stone burden on the proximal and distal curl.[57] Once the stone burden is quantified, the distal curl should be addressed first, often with cystolitholapaxy. Once this is completed, then the proximal curl can be managed. Both URS and percutaneous approaches are acceptable, but the choice of procedure will depend on the ability of the URS to be placed alongside the encrusted stent and also the quantity of stone to be removed.

Conclusions

Although URS is commonly employed across an increasing range of indications, complications are becoming rarer. When they do occur they are often minor and can be treated conservatively. To minimize the potential for complications, proper patient selection, case preparation, and sound endoscopic technique are all critical. When an intraoperative complication does occur, early recognition, and then appropriate management, usually with abortion of the procedure and placement of a ureteral stent, is sufficient. Early and late postoperative complications, although rare, can be serious, especially the development of infection and stricture, and therefore appropriate follow-up is necessary after the procedure.

References

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Chapter 27 Questions

1. Prior to any endoscopic procedure of the upper urinary tract the minimum preoperative laboratory evaluation in all patients should include which of the following?
   a. Urinalysis with microscopy or urine culture
   b. Basic metabolic panel
   c. Complete blood count
   d. Coagulation panel
   e. Serum calcium

2. You have just completed a time-out for patient safety prior to starting a routine ureteroscopy for a 5-mm midureteral stone. What medication should you ensure is administered prior to scope insertion?
   a. Antimicrobial prophylaxis
   b. Mannitol
   c. Methylene blue
   d. Lasix
   e. Heparin

3. In the course of a ureteroscopy for removal of a 7-mm proximal ureteral stone, you begin by placing a wire into the ureteral orifice. However, as you advance the wire up the ureter under fluoroscopic guidance you encounter resistance at the proximal ureter. Which one of the following would be an appropriate next step?
   a. Use excessive force to drive the wire past the area of resistance
   b. Exchange the wire for a ureteral catheter and perform a retrograde pyelogram
   c. Convert the procedure to a percutaneous nephrolithotomy
   d. Convert the procedure to a shockwave lithotripsy
   e. Abort the procedure

4. You are consulted by the emergency department to see a patient with a 1-cm obstructing distal ureteral stone with resultant moderate hydronephrosis. The patient's only complaint is persistent flank pain. You elect to proceed with ureteroscopy and laser lithotripsy. At the start of the case, you place a guidewire into the ureteral orifice, and there is an immediate return of purulent material. Which one of the following would be an appropriate next step?
   a. Proceed with ureteroscopy and laser lithotripsy
   b. Place a ureteral stent and delay ureteroscopy
   c. Abort the procedure without urinary drainage
   d. Convert the procedure to a percutaneous nephrolithotomy
   e. Convert the procedure to a shockwave lithotripsy

5. You would like to approach an 8-mm lower pole renal stone with ureteroscopy and laser lithotripsy. You start the case by placing both a working and safety guidewire into the renal collecting system without issue. However, as you attempt to advance the ureteroscope over the working wire and into the distal ureter you meet resistance. The scope cannot be advanced. Which one of the following would be an appropriate next step?
   a. Use excessive force to drive the ureteroscope past the area of resistance
   b. Place a ureteral stent for passive dilation and delay ureteroscopy
   c. Abort the procedure without urinary drainage
   d. Convert the procedure to a percutaneous nephrolithotomy
   e. Convert the procedure to a shockwave lithotripsy

6. What is the contemporary reported rate of ureteral stricture development after ureteroscopy?
   a. 1.5%
   b. 1%
   c. 0.5%
   d. 0.3%
   e. 2.0%

7. You are performing ureteroscopy for an 8-mm midureteral stone. You visualize the stone, and it appears partially impacted in the ureteral mucosa. You begin with laser lithotripsy. After several minutes, you notice a ureteral perforation with periureteral fat visible. You have a safety wire in place. Which one of the following would be an appropriate next step?
   a. Terminate ureteroscopy and place a ureteral stent
   b. Complete ureteroscopy with laser lithotripsy but without fragment extraction
   c. Complete ureteroscopy with laser lithotripsy and fragment extraction
   d. Convert the procedure to a percutaneous nephrolithotomy
   e. Convert the procedure to a shockwave lithotripsy

8. You have successfully performed laser lithotripsy on a 1-cm renal pelvis stone. The stone is now in several fragments in the renal pelvis. You proceed to remove the fragments with a nitinol basket. After engaging one of the fragments, you withdraw the basket into the ureter, but it becomes entrapped in the proximal ureter. You cannot disengage the basket from the stone. Which one of the following would be an appropriate next step?
   a. Use excessive force to move the basket past the area of entrapment
   b. Disassemble the external basket housing and then attempt to disengage it from the stone
   c. Terminate ureteroscopy and place a ureteral stent
   d. Convert the procedure to a percutaneous nephrolithotomy
   e. Convert to an open ureterolithotomy

9. What is the contemporary reported rate of postoperative complications from ureteroscopy, and which one is the most common?
   a. 3.5%; Fever
   b. 3%; Urinary tract infection
   c. 2.5%; Sepsis
   d. 0.6%; Ureteral stricture
   e. 1.0%; Death

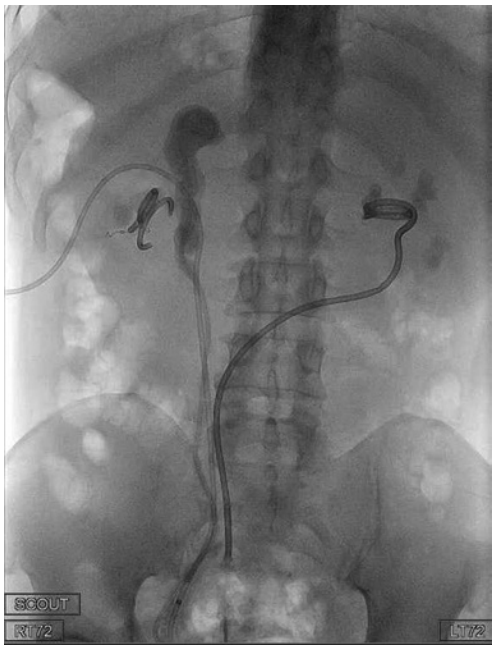
10. You are called into the operating room by your colleague who encountered a complication during ureteroscopy. When you enter the operating room, you

recognize the ureteroscope, the basket containing a stone fragment, and the ureteral mucosa all externalized per urethra. You are concerned about a ureteral avulsion. Which one of the following would be an appropriate next step?
a. Immediate surgical exploration with primary repair
b. Immediate cystoscopy with ureteral stent placement
c. Immediate percutaneous nephrostomy tube
d. Immediate nephrectomy
e. Immediate abortion of the procedure without urinary drainage

Case Studies

CASE 1

A 53-year-old gentleman presents to your clinic to re-establish care after undergoing bilateral ureteroscopy for bilateral renal stones approximately 1 year prior by another provider. He states that he had bilateral ureteral stents placed after the procedure, but he never returned to have them removed. He is currently asymptomatic without flank pain. You obtain point-of-care labs in your office, and these are significant for a creatinine of 1.2 mg/dL and a urinalysis positive for leukocytes. You order a kidney-ureter-bladder x-ray. This is shown below (Case Fig. 27.1).



Case Figure 27.1

1. What complication following ureteroscopy is depicted in this image?
   a. Retained and encrusted ureteral stent
   b. Ureteral stricture
   c. Emphysematous pyelonephritis
   d. Urethral stricture
   e. Horseshoe kidney

You discuss with the patient that surgical intervention is necessary to remove both the residual renal stones and retained ureteral stents.

2. What additional study would be the most appropriate prior to proceeding with surgical intervention?
   a. Computed tomography
   b. Renal ultrasound
   c. Retrograde pyelogram
   d. Intravenous pyelogram
   e. Magnetic resonance imaging

You successfully perform a staged bilateral percutaneous nephrolithotomy removing his retained ureteral stents and clearing his renal stone burden. However, at the end of the procedure, you again place bilateral ureteral stents to facilitate urinary drainage. You plan on removing these in the office in 1 week.

3. To prevent a repeat complication from retained, encrusted ureteral stents what strategy would be the most appropriate to ensure timely removal and appropriate follow-up?
   a. Ureteral stent registry
   b. Allowing the patient to schedule follow-up
   c. Informing the patient that ureteral stents were placed
   d. Keeping the patient in the hospital until scheduled ureteral stent removal
   e. Ordering a medical alert bracelet for the patient

CASE 2

A 66-year-old woman presents to your office with a 1-cm left-distal ureteral stone without hydronephrosis detected incidentally on a CT scan performed for back pain. You discuss her options for treatment, and she elects to proceed with a left ureteroscopy and laser lithotripsy. You perform this without complication. You place a temporary ureteral stent, which is removed in the office 1 week later.

1. According to current professional guidelines, you should routinely perform which study after ureteroscopy?
   a. Renal ultrasound
   b. Basic metabolic panel
   c. Complete blood count
   d. 24-hour urine collection
   e. Urinalysis

You obtain a renal ultrasound approximately 6 weeks after ureteroscopy. The renal ultrasound demonstrates moderate-to-severe left hydronephrosis without evidence of a shadowing renal or ureteral calculus. You elect to proceed to the operating room for a left retrograde pyelogram to determine the etiology of the hydronephrosis. This is shown in Case Fig. 27.2.

2. What complication following ureteroscopy is depicted in this image?
   a. Retained ureteral stent
   b. Persistent ureteral calculus
   c. Ureteral stricture
   d. Ureteral avulsion
   e. Retained foreign body



Case Figure 27.2

3. In contemporary series, what risk factors are associated with the development of a ureteral stricture after ureteroscopy?
   a. Stone location
   b. Placement of ureteral stent prior to ureteroscopy
   c. Ureteral access sheath usage
   d. Manufacturer of ureteroscope
   e. None of the above

Answers

1. **a.** According the AUA Guidelines, one of the only absolute contraindications to proceeding with ureteroscopy is an active or untreated urinary tract infection. Therefore all patients need at least a urinalysis, preferably a urine culture to document no evidence of infection prior to the procedure. All the other choices can be obtained depending on local practice patterns but are not required.
2. **a.** According to the AUA Best Practice statement, ureteroscopy is an upper urinary tract procedure, and thus should receive antimicrobial prophylaxis prior to incision. The specific antibiotic depends on several factors, including local resistance patterns, but should cover common uropathogens. All the other medication choices can be given in select circumstances but are not required for every patient.
3. **b.** B is the only answer that is reasonable at this stage of the procedure. There is likely obstruction at the point where the wire met resistance. However, at this point, you do not know the reason for the resistance. Prior to any further manipulation, it is reasonable to perform a retrograde pyelogram to better assess why the wire met resistance. It may be as simple as a kink in the ureter. Using excessive force to drive the wire past the area of resistance is not reasonable and can lead to development of a false passage. It may be reasonable to abort the procedure for the future, but at this point you still do not have all the information. Therefore it is more reasonable to perform a retrograde pyelogram prior to aborting. For the same reason the procedure should not be converted to percutaneous nephrolithotomy. The procedure should also not be converted to shockwave lithotripsy if there is a blockage at that position in the ureter. Therefore once again a retrograde pyelogram should be performed first.
4. **b.** According to the AUA Guidelines, if purulent material is expressed after accessing the ureter, then infection is present, and immediate urinary drainage with abortion of the procedure is the accepted standard practice. All the other options would result in either continued manipulation of the urinary system with an increased risk of systemic inflammatory response syndrome or sepsis or would not drain the urinary system.
5. **b.** There are cases where the ureter will not accommodate the diameter of the ureteroscope. In this case, the options are active dilation with either serial dilation or balloon dilation. However, this is not one of the answer choices. Therefore the other option is placement of a ureteral stent with a return for a re-attempt at ureteroscopy at a later date. Successful access of the ureteroscope after passive dilation with a ureteral stent is almost always successful. The other options are reasonable, but if your desired approach is ureteroscopy, then this is the only option listed that is acceptable.
6. **d.** According to the CROES database, the contemporary reported rate of a ureteral stricture after ureteroscopy is now 0.3%. The other options are not what is currently reported in the literature.
7. **a.** If a ureteral perforation is witnessed, then the generally accepted standard practice is to abort the procedure and place a ureteral stent. By aborting the ureteroscopy and placing a ureteral stent, you prevent further injury to the area. The ureteral stent will facilitate healing of the area. All the other options are not reasonable, as they could lead to further injury to the area or do not involve placement of a ureteral stent to facilitate healing of the area.
8. **b.** This is the next step to allow the basket to be disengaged from the stone. Once the external basket housing is dissembled, the basket tines will separate. Typically, this will free it from the stone. Using excessive force can result in a ureteral avulsion. Terminating the procedure and placing a ureteral stent is not feasible until the basket is removed. Converting the procedure to a percutaneous nephrolithotomy is technically possible, but the next step is not, as you have not tried to dissemble the basket first. A similar rationale exists for not converting to an open ureterolithotomy.
9. **a.** This is the only answer with the correct percentage associated with the correct complication. Fever is the most common early complication. All the other complications with their associated risk are listed in Case Tables 27.1 to 27.3.
10. **c.** This is the most feared and devastating complication of ureteroscopy: ureteral avulsion. Thankfully, this is

Case Table 27.1 Intraoperative Complications of Ureteroscopic Surgery and Management

Complication	Risk Factor[a]	Etiology	Rate[b]	Management
Ureteral bleeding	Multiple ureteral locations Low-volume center	Dilation Misfired energy Mucosal injury	1.4%	Observation Ureteral stent
Ureteral erosion or false passage	Unknown	Wire placement Scope manipulation Misfired energy Instrument deployment Stone removal	Unknown	Observation Ureteral stent
Ureteral perforation	Midureteral location Low-volume center	Wire placement Scope manipulation Misfired energy Instrument deployment Stone removal	1.0%	Ureteral stent
Ureteral intussusception or avulsion	Low-volume center	Entrapped stone removed with excessive force	0.1%	Nephrostomy tube Delayed repair

([a]Adapted from Perez Castro E, Osther PJ, Jinga V, et al. Differences in ureteroscopic stone treatment and outcomes for distal, mid-, proximal, or multiple ureteral locations: the Clinical Research Office of the Endourological Society Ureteroscopy Global Study. Eur Urol. 2014 Jul;66(1):102-9; and Kandasami SV, Mamoulakis C, El-Nahas AR, et al. Impact of case volume on outcomes of ureteroscopy for ureteral stones: the Clinical Research Office of the Endourological Society Ureteroscopy Global Study. Eur Urol. 2014 Dec;66(6):1046-51.)
([b]Adapted from de la Rosette J, Denstedt J, Geavlete P, et al. The Clinical Research Office of the Endourological Society Ureteroscopy Global Study: indications, complications, and outcomes in 11,885 patients. J Endourol. 2014 Feb;28(2):131-9.)

Case Table 27.2 Early Postoperative Complications: Prevention and Management

Complication	Rate[a]	Prevention	Management
Bleeding	0.4%	Sound endoscopic technique	Observation Ureteral stent
Bladder spasms	0.4%	Avoid ureteral stent placement	Remove ureteral stent Anticholinergics Alpha-blockers
Fever	1.8%	Negative baseline urinalysis or culture Single-dose antimicrobial	Antimicrobials
Urinary tract infection	1.0%	Negative baseline urinalysis or culture Single-dose antimicrobial	Antimicrobials
Sepsis	0.3%	Negative baseline urinalysis or culture Single-dose antimicrobial	Fluid resuscitation Antimicrobials Cultures Imaging Source control
Venous thromboembolic	0.02%	Early ambulation Mechanical or pharmacologic in high-risk patients	Early recognition Anticoagulation
Cerebrovascular	0.02%	Preoperative medical evaluation	Early recognition
Acute myocardial infarction	0.01%	Preoperative medical evaluation	Early recognition
Death	0.02%	Preoperative medical evaluation	Early recognition

([a]Adapted from de la Rosette J, Denstedt J, Geavlete P, et al. The Clinical Research Office of the Endourological Society Ureteroscopy Global Study: indications, complications, and outcomes in 11,885 patients. J Endourol. 2014 Feb;28(2):131-9.)

now extremely rare. After ureteral avulsion there is no longer a viable ureter remaining. Therefore primary repair, ureteral stent placement, and abortion of the procedure without urinary drainage are not reasonable options. Immediate nephrectomy is theoretically an option. However, given the devastating nature of the injury and the inability of the patient to participate in the decision making while under anesthesia, it is reasonable to proceed directly with nephrectomy. Since this is not a life-threating emergency, an alternative is to place a nephrostomy tube to allow for urinary drainage. This will allow appropriate shared decision making with patient in a delayed fashion.

CASE 1

1. **a.** The imaging demonstrates bilateral stents, one in each kidney. Surrounding the proximal curl of each stent is

Case Table 27.3 Late Postoperative Complications: Prevention and Management

Complication	Rate[a]	Prevention	Management
Readmission	8.4%	Sound endoscopic technique	Early recognition variable
Ureteral stricture	0.3%	Sound endoscopic technique	Postoperative imaging Endoscopic dilation or incision Open or laparoscopic repair
Encrusted/ retained ureteral stent	Unknown	Avoid ureteral stent placement Patient counseling Ureteral stent registry	Postoperative imaging Endoscopic removal

([a]Adapted from de la Rosette J, Denstedt J, Geavlete P, Keeley F, Matsuda T, Pearle M, et al. The Clinical Research Office of the Endourological Society Ureteroscopy Global Study: indications, complications, and outcomes in 11,885 patients. J Endourol. 2014 Feb;28(2):131-9.)

stone material. The imaging does not show a ureteral stricture, which usually cannot be demonstrated without contrast. Emphysematous pyelonephritis is a gas-forming infection of the renal parenchyma. There is no evidence of gas around the kidneys. A urethral stricture would not be demonstrated on a plain x-ray. Similar, there is no suggestion of an isthmus on this imaging, which is characteristic of a horseshoe kidney.

2. **a.** A CT is the best imaging study, since it will clearly demonstrate kidney stone and will also provide anatomic information for operative planning. The other imaging modalities will provide you with more information than a plain x-ray, but none is superior to a CT to identify both stone and anatomy.
3. **a.** Several studies have demonstrated the effectiveness of a ureteral stent registry in preventing the "forgotten ureteral stent." Allowing the patient to schedule follow-up is reasonable, but there are patients who will not schedule that follow-up. Informing the patient that ureteral stents were placed should always be done, but this alone will not prevent patients from being lost to follow-up. Keeping the patient in the hospital for 1 week is not practical. Ordering a medical alert bracelet is an option, but again, that will only remind the patient, and he or she can still be lost to follow-up.

CASE 2

1. **a.** According to the AUA Guidelines, a renal US is recommended after ureteroscopy. This is to ensure clearance of all residual stone fragments and detect silent obstruction. All the other options are reasonable to perform if clinically indicated but are not required.
2. **c.** This image demonstrates a ureteral stricture. There is a narrowing and then a transition point with proximal hydroureter. These findings are classic for a ureteral stricture. A retained ureteral stent, foreign body, or persistent ureteral calculus would be visible as a filling defect. The clinical scenario is not suggestive of a ureteral avulsion. However, on retrograde pyelogram this would demonstrate extravasation of contrast.
3. **e.** Although each of these was once thought to be related to the development of a ureteral stricture, recent studies have suggested otherwise. It is now accepted that none of these factors either increases (stone location or ureteral access sheath) or decreases (prior ureteral stent placement) the risk of a ureteral stricture after ureteroscopy.

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28 Complications of Percutaneous Renal Surgery

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CHAPTER OUTLINE

Hemorrhage
Intraoperative Hemorrhage
Antegrade Endopyelotomy
Tubeless Percutaneous Renal Surgery
Postoperative Hemorrhage
Collecting System Injuries
Perforation and Extravasation
Ureteral Avulsion
Extrarenal and Extraureteral Stone Fragment Migration
Stricture
Infundibular Stenosis
Retained Foreign Bodies
Tumor Seeding
Nephrocutaneous Fistula
Injury Resulting From Energy Sources
Injury to Adjacent Structures
Lung and Pleura
Colon
Small Intestine
Liver, Gallbladder, and Spleen
Lymphatics
Medical Complications
Infection and Sepsis
Fluid Overload
Hypothermia
Positioning-Related Injuries
Air Embolism
Deep Vein Thrombosis and Pulmonary Embolism
Mortality
Loss of Renal Function
Conclusions
Chapter 28 Questions and Answers

KEY POINTS

1. Hemorrhage, the most common complication of percutaneous renal surgery (PRS), can occur intraoperatively or postoperatively. It is usually managed conservatively with blood transfusion if needed. If more profound bleeding is encountered, angiographic evaluation or open exploration may be required.
2. In patients with delayed postoperative bleeding, one should have a high index of suspicion for an arteriovenous fistula or pseudoaneurysm. This complication can be managed conservatively in most cases, although patients in whom conservative management fails should be treated with angiography and selective embolization.
3. Perforation of the collecting system should be suspected if perirenal or renal sinus fat is visualized during endoscopy. When perforation is recognized, the procedure should be terminated, and a nephrostomy tube should be left in place.
4. Tumor seeding is a potential but rare complication of percutaneous resection of urothelial carcinoma. It can be minimized by proper selection of patients with low-grade, noninvasive tumors.
5. The lung and pleura are the perirenal structures at greatest risk of injury. Intraoperative fluoroscopy of the chest is recommended at the end of PRS to rule out obvious hydrothorax or pneumothorax. Postoperative chest radiography is not required unless patients develop signs of pulmonary compromise.
6. Patients at higher risk for colonic injury include patients with congenital anomalies such as horseshoe kidneys, colon distention, or previous colon surgery. Preoperative CT imaging should be performed to evaluate for retrorenal colon.
7. In a stable patient, colonic perforation is managed by retraction of the nephrostomy tube into the colon, placement of an indwelling ureteral stent and Foley catheter, use of broad-spectrum antibiotics, and institution of a low-residue diet. This approach allows healing in the majority of cases.
8. Negative preoperative urine culture results do not predict negative stone or pelvic urine culture results. Therefore, it is recommended to start patients on antibiotics (i.e., fluoroquinolones, nitrofurantoin) 1 week preoperatively if there is suspicion of an infected or infection-

based (struvite, carbonate apatite) stone. There are few data at this time to recommend long-term postoperative antibiotics.

9. Multiple positioning methods are possible for PRS, with each position having varied reported advantages and disadvantages. No matter the positioning chosen, careful padding of all pressure points and avoidance of overextension of joints can decrease the risk of positioning-related injuries.
10. The effects of PRS on renal function appear minimal. Many patients undergoing percutaneous nephrolithotomy (PCNL), particularly for staghorn calculi, have deterioration of their renal function over time, although this is likely due to their stone disease.

Percutaneous renal surgery (PRS) is commonly employed to treat a variety of urologic conditions, from stone disease to upper tract urothelial carcinoma. Despite increasing surgical experience and advances in technology, complications can still occur. Prompt recognition of complications along with timely treatment can minimize the impact. This chapter reviews the spectrum of complications that can occur during and after PRS. Diagnosis, treatment, and preventive measures are presented.

Hemorrhage

INTRAOPERATIVE HEMORRHAGE

Patients undergoing PRS are at risk for significant intraoperative bleeding and subsequent blood transfusion. The transfusion rates from various contemporary series have ranged from 1% to 34%.[1–7] Several factors have been shown to be associated with an increased risk for transfusion. These include surgical technique, surgeon experience, preoperative anemia, advanced patient age, increased stone surface area, and the need for multiple tracts.[4,6,8] Intraoperative complications such as infundibular tear or pelvic wall tear have been shown to significantly increase blood loss. Other factors that have been shown to predict increased blood loss during PRS include diabetes, longer operating time, and increased parenchymal thickness.[6,8]

Proper preoperative workup of the patient is necessary to decrease risks of intraoperative hemorrhage. Perioperative use of anticoagulation is a controversial topic and should be discontinued in the proper time frame to allow the anticoagulant effect to wear off whenever possible. However, with the increased use of anticoagulants, studies are now being performed to evaluate the safety in performing PRS while on anticoagulation. Current evidence demonstrates that some medications such as aspirin, which were typically stopped in the perioperative period, need not necessarily be witheld. Leavitt and colleagues performed a retrospective review of 321 patients showing that perioperative use of aspirin is not associated with higher rates of bleeding complications.[9] While there is no guideline for management of these medications at this time, proper discontinuation and administration of other anticoagulation therapies allow for successful PRS without an increase in bleeding or thromboembolic complications.[10,11] Lange and associates evaluated the safety and efficacy of perioperative removable inferior vena cava filter placement in patients who were at significant risk for a venous thromboembolic event, allowing for complete discontinuation of these medications; bleeding and thrombotic complications were absent, although this may not be a satisfactory option in all patients.[12]

Operative technique is a modifiable risk factor, and certain principles, if followed, can help to reduce the risk of significant blood loss. For the prone approach, the collecting system should be accessed through a posterior calyx along the direction of the infundibulum. This technique avoids the blood vessels that course adjacent to the infundibulum.[13] The posterior calyx that provides the most direct access to the targeted stone should be chosen. Once access is established, the tract should be dilated only up to the peripheral aspect of the collecting system. Care should be taken not to dilate the tract too far medially because this increases the risk of pelvic wall tear and injury to the hilar vessels. Stoller and colleagues reported that renal pelvic perforation is a risk factor for excessive blood loss.[4]

The impact on blood loss by the method of tract dilation is controversial. Davidoff and Bellman found that the use of balloon dilators was associated with significantly less blood loss and lower transfusion rates when compared with the Amplatz serial dilators.[14] More recently, the Endourological Society Percutaneous Nephrolithotomy Study Group found that balloon dilation and larger sheath size were associated with bleeding and transfusion risk, although on multivariate analysis only sheath size remained significant.[15] Another series demonstrated that Alken serial dilators were associated with significantly greater blood loss than were either balloon dilators or Amplatz dilators.[6] Turna and colleagues reported that Amplatz serial dilators were associated with significantly greater blood loss compared with balloon dilation.[8] However, Osman and associates reported on 300 patients who had tracts dilated with Alken dilators, none of whom required a transfusion.[16] Other investigators have found no difference in blood loss among methods of dilation, including a one-shot dilation with a 25- or 30Fr Amplatz dilator.[4,17,18] Additional experimental techniques for tract creation and dilation are under investigation, including a method utilizing bipolar plasma vaporization of the renal tissue for tract formation, which was noted to be safe and effective in decreasing operative blood loss.[19]

Once access is obtained and the tract is dilated, a working sheath is often placed. Tract and sheath size appear to be one of the strongest risk factors for operative blood loss, but regardless of tract size, care must be taken to keep the working sheath in the collecting system to limit parenchymal bleeding.[20] Excessive torquing of rigid instruments through the working sheath may injure renal parenchyma and vasculature and therefore should be avoided. Flexible nephroscopy or placement of additional nephrostomy tracts should be performed instead, as demonstrated by Lam

and colleagues.[21] These investigators reported that the use of multiple tracts and flexible instruments decreased transfusion rates for their patients undergoing percutaneous nephrolithotomy (PCNL) in the treatment of staghorn calculi. Accessing the appropriate calyx, or using multiple access tracts when appropriate, can reduce the amount of blood loss and the number of complications.[22–24] Care must also be taken when removing stone fragments through an access sheath because sharp fragments can tear the sheath. Further manipulation of the fragments and sheath can lead to significant bleeding.[25]

When access is achieved and the working sheath is in place, it is not unusual for some bleeding to continue. However, if bleeding is such that visibility is compromised, certain measures should be taken. First, the surgeon should assess the position of the working sheath. If the end of the sheath has withdrawn into the parenchyma, simply repositioning the sheath back into the collecting system may correct the problem. If this maneuver does not correct the problem, or if the sheath is not malpositioned to begin with, then other interventions need to be undertaken. Inflation of a 30Fr dilating balloon in the tract for 10 to 20 minutes with subsequent placement of a large nephrostomy tube (24–28Fr) usually controls the bleeding. If bleeding persists, the nephrostomy tube should be clamped for 2 to 3 hours to allow the blood to clot and tamponade the injured vessel(s). Administration of mannitol may hasten this process by causing renal swelling within the capsule that may help tamponade vessels along the nephrostomy tract.[4,26] The nephrostomy tube is left to straight drainage when unclamped if the patient has no signs of continued bleeding.

If these maneuvers are unsuccessful, a specialized nephrostomy tamponade catheter can be inserted (Kaye, Cook Medical, Spencer, IN).[27] This catheter has a peripherally located balloon that is inflated in the nephrostomy tract while urine drains through the inner core. The catheter is typically left inflated for 2 to 4 days. The aforementioned measures are usually successful in controlling bleeding from peripheral vessels along the nephrostomy tract. Significant bleeding can also arise from injury to the main renal vein, and this bleeding can be controlled using a tamponade approach. Gupta and colleagues reported successful management of this complication in four patients by inflating a Council balloon catheter adjacent to the point of venous injury.[28] Additionally, Millard and associates noted the success of a hemostatic "sandwich" method whereby two nephrostomy tubes are left, one with the balloon inflated within the collecting system and the second inflated just under the skin within the tract; the region between the balloons was injected with hemostatic sealant with excellent hemostasis.[29] When these measures fail, or when significant arterial injury is suspected, then one should proceed expeditiously to renal angiography with selective embolization.

Antegrade Endopyelotomy

Percutaneous endopyelotomy has the additional risk of bleeding when the ureteropelvic junction (UPJ) is incised. DiMarco and colleagues reported a transfusion rate of 1.3% in their series of antegrade endopyelotomy.[30] In cases involving secondary UPJ obstruction or ectopic kidneys, preoperative imaging with computed tomography (CT) or magnetic resonance angiography is recommended to delineate vascular anatomy. Some investigators advocate the use of endoluminal ultrasonography (US) for this purpose.[31,32] Hendrikx and associates reported the use of endoluminal US, which detected 15% more crossing vessels than CT angiography and concluded that its use better prevents bleeding complications.[32] When significant hemorrhage arises from the incised UPJ, a 24Fr balloon should be inflated across the area and left in place for 10 minutes. If bleeding persists once the balloon is deflated or the patient becomes hemodynamically unstable, the balloon is reinflated, and renal angiography should be performed with embolization if possible. Rarely, open surgical exploration with possible nephrectomy may be necessary if the previous measures fail.

Tubeless Percutaneous Renal Surgery

Nephrostomy tube–free, or tubeless PRS, has become more prevalent over the past 10 years. The reported advantages of tubeless PRS are decreased pain and speedier recovery leading to decreased length of stay.[33,34] The transfusion rates for tubeless PRS have been reported to be approximately 5%, while the rate of stone clearance has been reported to range from 83% to 93%.[33,35,36] Success has been shown in cases with supracostal access and for larger stone burdens, although patients with continued bleeding at the end of the procedure should have a nephrostomy tube left in place to control and monitor bleeding.[33,36,37]

Certain techniques have been applied to tubeless PRS to minimize blood loss and the risk for transfusion. Jou and associates performed electrocauterization of bleeding points along the nephrostomy tract and inside the collecting system.[38] These investigators found that this method leads to a significantly lower transfusion rate. They were able to obtain a bloodless tract in 33.7% of patients, and these patients were left without a nephrostomy tube. When bleeding persists, these investigators advocate leaving a nephrostomy tube in place.

Hemostatic fibrin glue can be placed in the nephrostomy tract to aid in hemostasis. Shah and associates reported on the use of Tisseel Vapor Heated Sealant (Baxter AG, Vienna).[39] They prospectively compared patients who underwent tubeless PRS with Tisseel sealant placed in the tract at the end of the case to those without Tisseel sealant. These investigators found no significant difference in the change in hematocrit between the two groups, and other groups have duplicated this result as well.[40] Of note, a small prospective trial of tract closure methods showed that patients who underwent tract instillation of a gelatin matrix hemostatic sealant noted an initial increase in postoperative pain.[41] Additionally, care must be taken to avoid injecting the Tisseel sealant into the collecting system because it can form a solid clot that could possibly obstruct the collecting system.[42] A meta-analysis was performed to review the safety and efficacy of hemostatic agent use in tubeless PRS; overall these agents were noted to be safe although costly and not significantly beneficial.[43]

POSTOPERATIVE HEMORRHAGE

Patients continue to be at risk for significant bleeding for the first several weeks postoperatively.[5,7,44] Most patients who bleed postoperatively can be managed conservatively, but approximately 1% will require invasive treatments.[5,7,14,44] If bleeding occurs with the nephrostomy tube in place, the

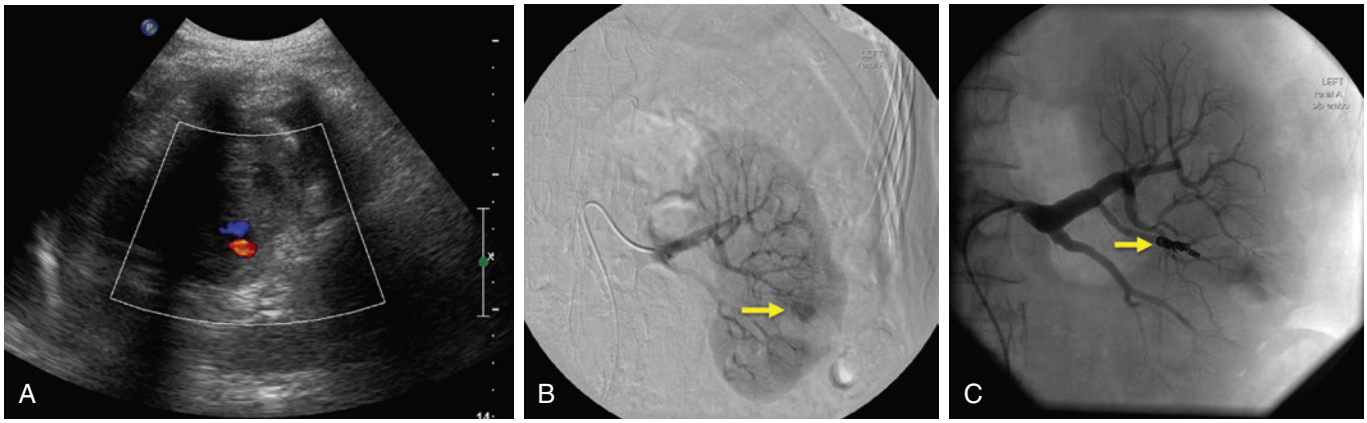


Figure 28.1 Pseudoaneurysm and vascular injury requiring selective angioembolization. A, Renal US scan demonstrating the "yin-yang" sign of vascular disease. B, Renal angiogram demonstrating a pseudoaneurysm of an midpole vessel (arrow). C, Selective embolization of the pseudoaneurysm, coils seen occluding the vascular injury (arrow). (B, C courtesy of Dr. Brian Eisner.)

measures discussed earlier may be employed, although it should be noted that large-bore nephrostomy tubes (>18Fr) are associated with lower bleeding complications than small-bore tubes.[45] If significant bleeding from the tract is encountered after removal of the tube, digital tamponade should be performed with subsequent placement of a tamponade catheter or large nephrostomy tube under fluoroscopic guidance. If a nephrostomy tube is placed, it should be clamped. The patient should then be placed on bed rest and transfused as needed. Renal angiography with selective angioembolization should be performed on patients who continue to require blood transfusions or who become hemodynamically unstable.

Delayed bleeding often occurs approximately 1 to 3 weeks postoperatively.[5,7,44] When angiography is performed on these patients, the most common causes of bleeding are laceration of a segmental artery, arteriovenous malformation, pseudoaneurysm, and arteriovenous fistula.[1–3,5,7,46] Renal angiography with selective embolization is highly effective in treating these lesions (Fig. 28.1).[5,7,44] The nephrostomy tube must sometimes be removed so that the bleeding site may be localized during these procedures. When renal angiography and embolization are unsuccessful, open surgical exploration with vascular repair or nephrectomy may be necessary. El-Nahas and colleagues reported on 39 (1.3%) of 2909 patients (3878 PCNL procedures) over a 10-year period who had severe perioperative bleeding requiring renal angiography and embolization.[7] Twenty-nine of these patients had severe bleeding before discharge, where the other 10 patients developed bleeding after discharge at a mean of 6.3 days. Renal angiography with selective embolization was successful in treating 36 of the 39 patients. The other three patients required exploration, and one required nephrectomy. These investigators identified upper calyx puncture, solitary kidney, staghorn stone, multiple punctures, and operator inexperience as significant risk factors for severe bleeding.[7] In another large series, Srivastava and colleagues identified stone size as the only significant risk factor predicting these serious vascular complications.[5] A similar series noted that tubeless surgery was associated with postoperative bleeding as well.[47]

Kessaris and colleagues reported that 17 of 2200 patients (0.8%) who underwent PRS over a 10-year period required angiography and embolization for uncontrolled significant bleeding.[44] Twenty-four percent of these patients presented in the immediate postoperative period (<24 hours), 41% in the early postoperative period (2–7 days), and 35% in the late postoperative period (>7 days). Superselective or selective angiographic embolization of such lesions, using Gianturco coils, absorbable gelatin sponges, or platinum microcoils, is generally quite successful. This study reported success in 15 of 17 such cases with selective or superselective embolization.[44,46] Failures of angioembolization have been related to the number of percutaneous access sites, more than two bleeding sites found on angiography, and use of gelatin sponge alone for embolization.[48]

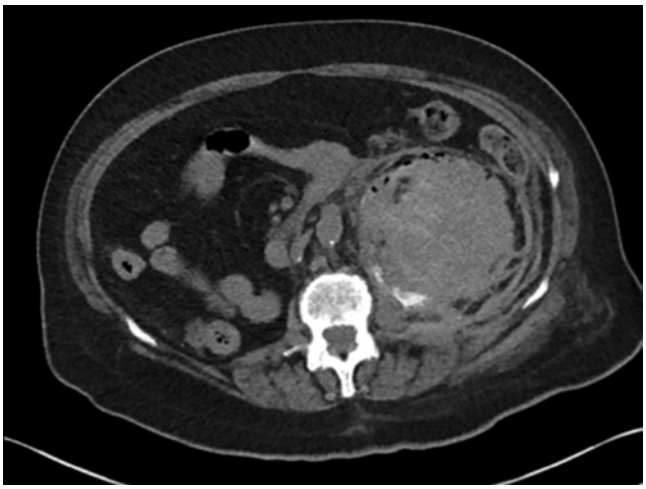


Figure 28.2 Perinephric/subcapsular hematoma displacing the left kidney after attempted percutaneous nephrostomy tube placement by interventional radiology.

Another cause of perioperative bleeding after PRS is perinephric hemorrhage (Fig. 28.2). This complication should be suspected in patients who have decreasing hemoglobin with clear urine draining from both the nephrostomy tube and the bladder. Perinephric hemorrhage can occur in cases with difficult access or in cases with thin parenchyma where bleeding occurs extrarenally, rather than into the collecting system. Malpositioning of the working sheath outside the renal parenchyma is another possible cause.

"Sandwich therapy" with shock wave lithotripsy and subsequent second-look PCNL is another potential risk

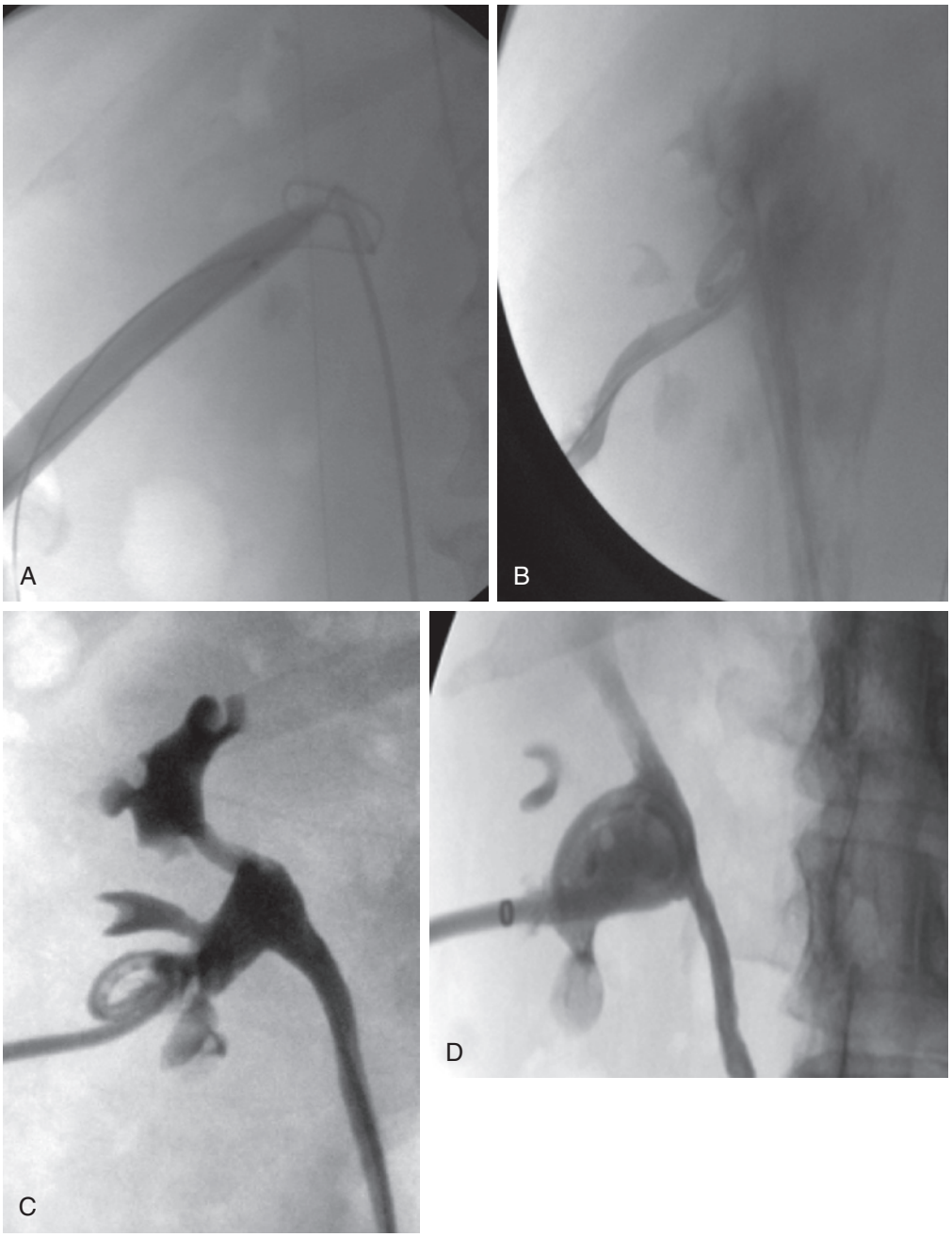


Figure 28.3 Renal pelvis injury/perforation with extravasation. A, Initial access with balloon dilator with wires in position. B, Perforation noted intraoperatively as nephrostogram demonstrates extravasation. C, Postoperative nephrostogram after 36 hours confirms healing of the renal pelvis. D, Nephrostogram at 1 week upon removal of nephrostomy tube shows complete resolution of extravasation. (Courtesy of Dr. Brian Eisner.)

factor. In these situations, subcapsular or perinephric hemorrhage caused by shock wave lithotripsy may be exacerbated by further tract and collecting system manipulation. Patients in whom this is suspected should be evaluated with CT scan. This situation can typically be treated conservatively with monitoring of hemoglobin, serial physical examinations, hemodynamic parameters, and imaging as needed because the bleeding is usually confined to the retroperitoneal space. Affected patients should be treated with blood transfusions as needed, and rarely exploration may be required if hemodynamic instability cannot be controlled or if bleeding is persistent.

Collecting System Injuries

PERFORATION AND EXTRAVASATION

Perforation of the collecting system can occur any time during PRS (Fig. 28.3). When the working sheath is located outside the collecting system secondary to perforation, large amounts of fluid can extravasate. Additionally, newer access methods including micropercutaneous nephrolithotomy may introduce a significant increase in renal pelvic pressure leading to perforation.[49] Lee and associates reported that perforation with extravasation occurred in

7% of 582 cases of PCNL.[50] Perforation should be suspected if perirenal or renal sinus fat is visualized, if other perirenal structures are visualized, or if the patient's abdomen or flank becomes distended. Large amounts of fluid can quickly accumulate in the retroperitoneal space or, less commonly, the abdominal cavity. This fluid can cause difficulties in ventilating the patient during the procedure, electrolyte and hemodynamic abnormalities secondary to fluid absorption, and ileus postoperatively.[51]

CT- or US-guided percutaneous drainage of the fluid is sometimes necessary if the patient is having respiratory distress, if prolonged ileus does not resolve spontaneously, or if infection of the fluid is suspected. Once perforation is recognized, serious consideration should be given to terminating the procedure. If the procedure is nearly completed, it may be possible to complete it with low-flow irrigation, provided the patient remains stable. Concerns that arise when the procedure is continued are stone migration outside the collecting system and tumor cell spillage during percutaneous resection of urothelial carcinoma, both discussed later in this chapter. Once the procedure is terminated, a nephrostomy tube should be left in place. Most perforations heal in 72 hours, but it may be prudent to wait 7 days and perform a nephrostogram to confirm closure of the perforation before going back to complete the stone extraction or tumor removal. On rare occasions, open surgical repair or nephrectomy may be necessary.[50,52] This complication can be limited by paying close attention to proper access and dilation techniques (e.g., preventing sheath placement significantly beyond the balloon or sequential dilator, preventing dilation of and avoiding access sheath placement through narrow infundibuli), by taking care to keep the working sheath in the collecting system, by judicious stone fragmentation, and by fluoroscopic monitoring of nephrostomy tube insertion and removal.

URETERAL AVULSION

Ureteral avulsion is an extremely rare complication of PRS. It is most commonly caused by attempts at basketing of large, impacted ureteral stones, but it can also occur with dilation or incision of the UPJ and tumor resection.[50,53] Additionally, a "scabbard" injury can occur rarely when performing antegrade ureteroscopy (typically in cases where the ureter has not been pre-stented or is narrow at baseline and with greater risk when using a semirigid ureteroscope in a retrograde manner) where the ureteroscope is down the ureter; the proximal shaft of the scope is larger in caliber than the tip, therefore the proximal shaft may be tight in the ureter. When removing the scope, the tissue adheres to the scope and can lead to an injury in that region of the ureter where the scope is trapped. If this is occurring, very gentle removal of the scope is needed, and occasionally injection of lubrication via the scope or adjacent to the scope down the ureter can allow the ureteroscope to be removed safely. This can also theoretically occur if larger fragments or a high volume of fragments are left adjacent to the ureteroscope as the ureteroscope is advanced distally to treat additional stones. The friction in the ureter with these fragments as the ureteroscope is removed can give resistance, and great care is needed to gently remove the scope to avoid an avulsion type of injury.

This complication mandates prompt open surgical exploration, although, when necessary, nephrostomy tube drainage may be used as a temporizing measure to allow stabilization of the patient. Occasionally, a percutaneous drain will need to be inserted into the potential urinoma if the nephrostomy tube alone is not able to adequately drain the majority of the urine produced by the affected kidney. This complication can be avoided by making sure stones are fragmented into pieces small enough to be removed by an extraction device, as well as by adhering to proper endopyelotomy, endoureterotomy, and resection techniques. Furthermore, when dealing with a narrow ureter that is unable to handle the capacity of a ureteroscope, safe dilation techniques are possible, or placement of a ureteral stent with return to the operating room several days later after passive dilation has likely occurred.

EXTRARENAL AND EXTRAURETERAL STONE FRAGMENT MIGRATION

Extrarenal and extraureteral stone fragments are generally not of any clinical consequence, provided the urine and stone are not infected and the stone is far enough from the collecting system and ureter not to cause periureteral inflammation with subsequent stricture formation (Fig. 28.4).[54,55] Intraperitoneal migration of stone fragments has also been reported; in this case open extraction was performed with success in order to prevent further peritoneal complications.[56] Endoscopic retrieval should not be attempted in most cases because this may enlarge the perforation. The occurrence of this complication can be minimized by avoiding collecting system perforation or, if one has occurred, recognizing it and stopping the procedure, as well as applying proper stone removal techniques.

STRICTURE

The development of a stricture following PRS occurs rarely, with a reported incidence of <1%. The most commonly affected segments are the proximal ureter and the UPJ.[1,2] Strictures can form as a result of inflammation secondary to stone impaction or from procedural trauma including intracorporeal lithotripsy and periureteral urine and/or stone extravasation. Patients who have undergone previous cutaneous urinary diversion and undergo PRS for proximal ureteral calculi may be at increased risk for stricture formation because of an intense inflammatory response (obliterative pyeloureteritis) that may be secondary to infection and other local factors.[57] Ureteral strictures can be asymptomatic, and patients undergoing PRS should be routinely evaluated for this complication with postoperative imaging.[58] Most ureteral strictures that develop after PRS can be managed with endourologic techniques, provided the stricture is <1 cm and is not in a radiated field. However, open or laparoscopic reconstruction may be required in patients with more extensive strictures or in patients in whom an endoscopic approach has failed.

INFUNDIBULAR STENOSIS

Infundibular stenosis is a rare complication that can occur after PRS.[2,59,60] Parsons and colleagues reported a

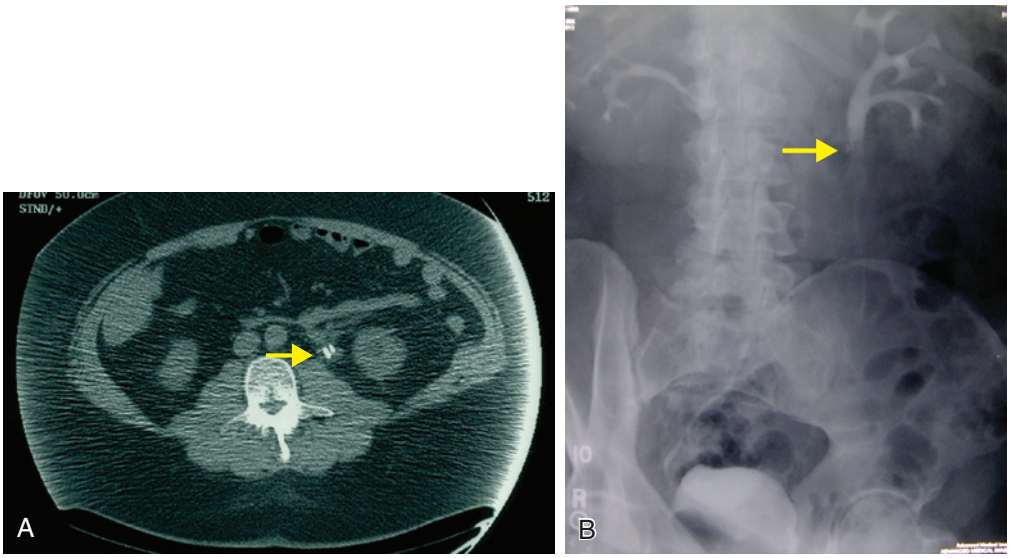


Figure 28.4 Left extraureteral stone. A, CT scan postoperatively demonstrates a stone fragment (arrow) adjacent to the ureteral stent in the region of the proximal ureter. B, Postoperative intravenous pyelogram reveals that the stone fragment lies adjacent to the left proximal ureter causing mild extrinsic compression (arrow) but no significant hydronephrosis and drainage of contrast material distally. (Courtesy of Dr. Joshua Wein and Dr. Rupa Patel.)

2% incidence following PCNL.[61] They identified prolonged operative time, large stone burden requiring multiple procedures, and extended postoperative nephrostomy tube drainage as independent risk factors for this occurrence. These investigators postulated that factors that increase local inflammation could include prolonged instrumentation or the use of large amounts of energy to break up stones. This complication is usually detected in the first year after PRS. Goel and associates noted a case of the formation of an excluded calyx, which was seen 2 weeks post PRS in a patient presenting with fevers, obstructed upper pole, and nonvisualization of this calyx on excretory urography.[62] This was treated with nephrostomy placement and eventual antegrade creation of neo-infundibulum with holmium:YAG laser. Infundibular stenosis should be managed endourologically, as in the above case, with open surgery reserved for those in whom this approach fails. For patients who are asymptomatic without evidence of impaired renal function, close observation is an option.

RETAINED FOREIGN BODIES

On occasion, a piece of equipment used in a percutaneous procedure can break off in the renal collecting system. This can occur during any stage of the procedure, including during postoperative renal embolization.[63] Lynch and associates reported on a piece of plastic drape that was translocated into the collecting system during tract dilation, while Kaba and colleagues noted the migration of a 2-cm fragment of ureteral catheter that was found on fluoroscopy to have migrated into the left lung, possibly intravascularly.[64,65] Instruments should be inspected periodically during and at the end of procedures to ensure that nothing is broken or missing. Every effort should be made to find the foreign body and remove it because it can act as a nidus for stone formation or infection or cause a granulomatous reaction within the kidney.

The foreign body can usually be extracted with a rigid or flexible nephroscope and graspers or a basket. Fluoroscopy can aid in removal of the foreign body if it is radiopaque. If the foreign body is discovered after nephrostomy tube removal, a retrograde ureteroscopic approach can be performed. If this fails, percutaneous extraction may be necessary. This complication can be limited by replacing instruments before instrument fatigue develops. Careful manipulation of wires, laser fibers, other lithotripter devices, baskets, and tubes can also minimize the incidence of this complication. Postoperatively, the tips of nephrostomy tubes, such as Malecot catheters, may become entrapped in the collecting system as a result of the ingrowth of fibrous and inflammatory tissue. If this occurs, it can be managed using a ureteroscopic approach or the creation of a new nephrostomy tract and endoscopic removal of this tissue.[66]

TUMOR SEEDING

Tumor seeding of the nephrostomy tube tract is a potential but rare complication of percutaneous resection of urothelial carcinoma. It has been reported after resection of poorly differentiated, locally invasive disease.[67] More commonly, it has been noted in association with percutaneous drainage of an obstructed system in patients with urothelial carcinoma.[68–70] Numerous series have performed percutaneous resection without evidence of tract seeding with long-term follow-up.[71–74] This complication can be minimized by proper selection of patients with low-grade, noninvasive tumors. Special care should be taken to maintain proper position of the working sheath, to perform the procedure with low-pressure irrigation, to have low-pressure postoperative drainage with properly sized nephrostomy

tubes, and to decrease operative times in these patients, when possible.

NEPHROCUTANEOUS FISTULA

Nephrocutaneous fistula formation is a rare occurrence after PRS.[75] It is usually caused by distal obstruction secondary to ureteral edema, obstructing stone, blood clot, or stricture. Delayed development of nephrocutaneous fistulas has been reported to occur in patients with genitourinary tuberculosis.[76] Fibrin glue has been used to assist with healing of the fistula, although this is usually unnecessary; relief of the distal obstruction by either placement of a ureteral stent or removal of stone usually allows the fistula to close without additional treatment at the fistula site.[77]

INJURY RESULTING FROM ENERGY SOURCES

The continued advances in design of lithotripsy and ablative energy sources have aided the performance of PRS. Although these advances have improved efficacy and safety, the potential for energy-related complications should not be underestimated. Intracorporeal damage from these sources can range from minor to extensive. To avoid these complications, the surgeon should have a thorough knowledge of each energy source before it is used.

Ultrasonic lithotripsy is a commonly used energy-source technique for PCNL.[53] Collecting system or ureteral perforation can occur with this device, especially if excessive pressure is applied to these tissues. The probe can become clogged with debris, thus causing overheating that could result in thermal injury. As mentioned earlier, a piece of the lithotripter can break off. A single case report noted that the tip of an ultrasonic lithotripter broke off and migrated to the left pulmonary artery.[78]

As a result of the development of newer devices with better safety profiles, electrohydraulic lithotripsy is used less frequently for PCNL.[79] The most common complications associated with electrohydraulic lithotripsy are perforation of the collecting system and bleeding, which are managed as previously described.

The holmium laser is commonly used for lithotripsy, for incision of strictures, and for the ablation of upper tract tumors. Although the laser has been shown to have an excellent safety profile, complications can still occur.[80] These include hemorrhage, perforation of the collecting system, and thermal injury. Investigators have also reported that heat generated from the laser can interact with hydrogen gas and can generate an explosion in the collecting system that leads to perforation and hemorrhage.[81] These complications can be minimized with careful technique and use of appropriate energy settings, which have not been standardized at this time. The typical energy settings during PCNL range from 0.5 to 3.0 joules and from 6 to 30 hertz, with a single study showing that higher power energy settings were associated with an increased risk of injury as 6/38 patients were found to have proximal ureteral stricture postoperatively.[82]

Pneumatic lithotripters and hybrid devices (pneumatic and US) are also used during PCNL.[83–85] A small risk of perforation and hemorrhage also exists with these devices.

Electrocautery and electroresection are used during PRS for resection of tumors and to control bleeding. The patient should be properly grounded to prevent thermal burns. Only nonconductive materials should be in contact with the collecting system and ureter to prevent current dispersal that could lead to thermal injury. Maintaining proper orientation with respect to adjacent vascular structures can minimize the risk of hemorrhage. When electrocautery or electroresection is performed, sterile glycine is typically used as irrigant, with an associated risk of fluid absorption and secondary hyponatremia. Maintaining the lowest possible irrigation pressures and limiting resection time can minimize this risk. Bipolar electrocautery devices can instead be used with sterile saline irrigation, thereby reducing the risk of hyponatremia from fluid absorption.

Injury to Adjacent Structures

LUNG AND PLEURA

The lung and the pleura are the perirenal structures most at risk of injury during PRS.[1,2] The incidence of intrathoracic complications has been reported to be between 0.3% and 15.3%.[86–90] These complications include pneumothorax, hydrothorax, hemothorax, and nephropleural fistulas (Fig. 28.5). They occur more commonly with supracostal access when compared with infracostal access.[86,88,89,91] Hopper and Yakes studied 43 randomly selected patients with CT imaging during maximal inspiration and expiration and predicted that during maximal expiration the pleura and lung would be traversed 86% of the time on the right and 79% of the time on the left with a supra–11th rib approach.[92] These investigators also predicted that the pleura and lung would be traversed 29% of the time on the right and 14% on the left with a supra–12th rib approach. These rates are higher than those noted clinically, with reported rates ranging from 3.3% to 15.3% for supracostal approaches, although one series did report hydrothorax in three of four cases performed with supra–11th rib access.[86–88]

Munver and colleagues analyzed their experience with supracostal access for PRS.[89] Of 300 total access tracts, 98 (32.6%) were supracostal, and of these 73.5% were supra–12th rib and 26.5% were supra–11th rib. The overall complication rate for supracostal access was 16.3% (supra–11th rib, 34.6%; supra–12th rib, 9.7%), significantly higher than the rate of 4.5% for subcostal approach in the same series. Seven of the eight intrathoracic complications in this report occurred during supracostal access, including six complications during supra–11th rib access. In a more recent series, Lojanapiwat and Prasopsuk reported a significantly greater incidence of hydrothorax with supra–12th rib access than with subcostal access (15.3% vs 1.4%), while el-Karamany noted a 10% incidence of hydrothorax with supracostal access.[88,93]

Studies have suggested that different operative positions may alter the risk of pleural injury, with a prone-flexed position displacing the kidney caudally and decreasing the need for supracostal access.[94] Additionally, the supine position allowed for subcostal upper calyceal access when the kidney

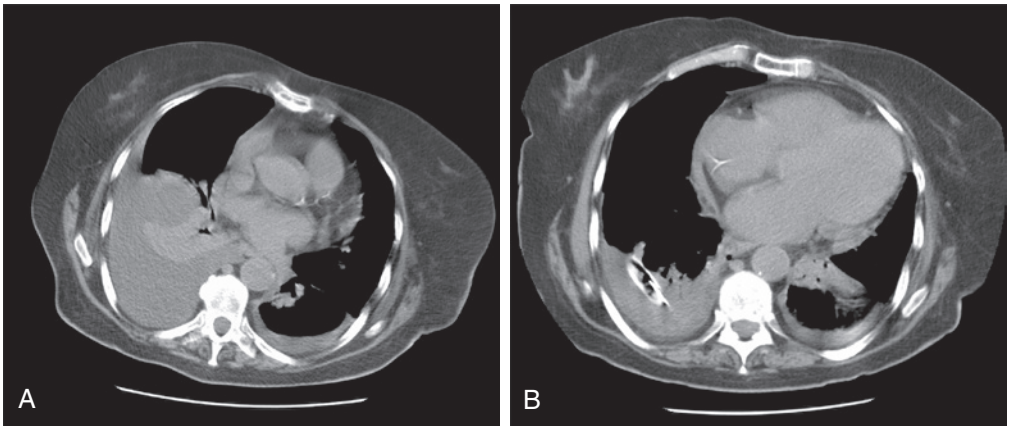


Figure 28.5 Hydrothorax. A, Chest CT scan demonstrates right hydrothorax. B, Hydrothorax was managed with tube thoracostomy. (Courtesy of Dr. Dean Assimos.)

was displaced with a lung inflation technique, avoiding possible intrathoracic complications.[95]

A working sheath should be used with a supracostal approach to provide a barrier to the influx of fluid and air into the pleural cavity if the parietal pleura is violated. Routine intraoperative chest fluoroscopy is recommended at the termination of PRS to evaluate for obvious hydrothorax or pneumothorax, and routine postoperative chest radiography is not required if results of fluoroscopy are normal and the patient has no signs of pulmonary compromise.[96] Preoperative CT imaging during expiratory and inspiratory phases with coronal, sagittal, and three-dimensional reformats may be used in preoperative planning of access tracts to avoid intrathoracic complications.[97]

Patients with small-volume, asymptomatic hydrothorax or pneumothorax can be observed. When patients exhibit signs of pulmonary compromise or become unstable, aspiration or tube thoracostomy may be required, although recent studies show that small-bore thoracostomy tubes may perform as well for drainage as traditional chest tubes.[98] In cases of PRS for struvite stones, if hydrothorax occurs, it is prudent to place a chest tube to prevent development of empyema from potentially infected irrigation fluid and urine. Rarely, thoracoscopy or formal thoracotomy may be required if the foregoing interventions fail or if complex pleural effusion or empyema develops.[99]

Nephropleural fistula can manifest intraoperatively, immediately postoperatively, or 1–2 weeks postoperatively. In the immediate postoperative period, this complication should be suspected if thoracic fluid persists despite tube thoracostomy drainage. Delayed nephropleural fistula should be suspected in patients who have undergone PRS and who present with shortness of breath with or without flank pain. The diagnosis is best made with retrograde pyelography. Treatment consists of draining the pleural fluid with tube thoracostomy and decompressing the collecting system with a ureteral stent or nephrostomy tube.[91]

The intercostal vessels can be lacerated during supracostal access, with resulting hemothorax. Tube thoracostomy and open surgical thoracotomy may be necessary if this complication occurs. To minimize the risk, access should be obtained directly above the rib to avoid the intercostal vessels.

COLON

Colonic perforation is a rare complication of PRS, reported in <1% of cases.[50,53,100–102] The likely reason for this low incidence is that the colon is rarely retrorenal. Hadar and Gadoth and Sherman and colleagues analyzed the relationship of the kidney and colon on CT scan and found that the colon was retrorenal in approximately 0.6% of individuals.[103,104] Patients at higher risk for colonic injury include those with congenital anomalies such as horseshoe kidney and other forms of renal fusion and ectopia, as well as those with colonic distention resulting from jejunoileal bypass, partial ileal bypass, neurologic impairment, and "institutional" bowel. Other proposed risk factors are lower pole puncture, left-sided procedure, previous colonic surgery, older age, and female sex.[100,105] El-Nahas and associates reviewed their experience with 5039 PCNL procedures to try to identify risk factors for colonic perforation.[101] These investigators reported 15 colonic perforations (0.3%). The only significant risk factors identified on multivariate analysis were older patient age and the presence of horseshoe kidney. Although there was concern that supine PCNL was a risk factor for colonic injury, this has not been borne out in the literature, with a similar proportion of colon injury in supine PCNL (0.5%).[106] Preoperative CT scan is recommended for PRS, and this should allow for detection of retrorenal colon in the majority of cases, and CT guidance can be used to direct percutaneous access in these patients.[107] Of note, given that patients often undergo percutaneous access in the prone position, there is some concern about the utility of preoperative supine CT for PRS planning. Chalasani and colleagues performed preoperative CT scans on patients in a prone position and found increased rates of retrorenal colon (16.2% of 265 kidneys), which is significantly higher than previous estimates of retrorenal colon, suggesting the value of preoperative prone CT scanning for operative planning.[108]

Early recognition and diagnosis of colonic perforation are of critical importance. Serious infectious complications can occur when diagnosis or management is delayed. Signs of colonic perforation include passage of gas or feculent material through or around the nephrostomy tube, intraoperative diarrhea or hematochezia, and peritonitis.[100,101,105,109] These

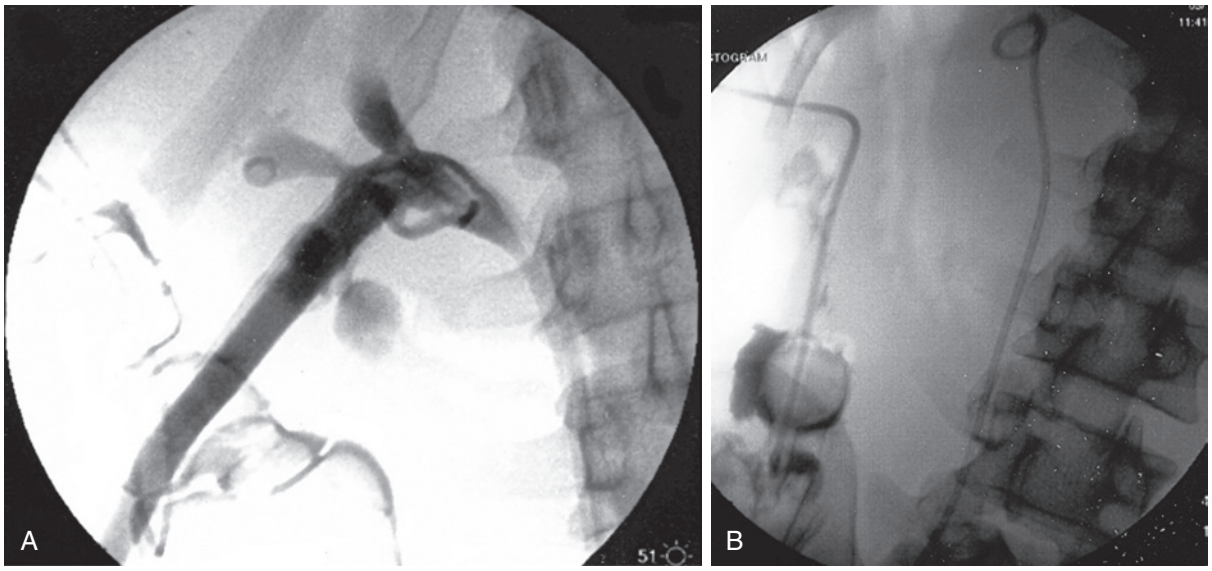


Figure 28.6 Colon injury. A, Postoperative nephrostogram demonstrates contrast within the large intestine. B, The nephrostomy tube was removed, and the colon tube was placed in addition to an indwelling ureteral stent and Foley catheter. The patient healed without complications, and the colon tube was removed 7 days later, when a cologram confirmed no evidence of fistula.

patients usually present with fever. Patients can present after the nephrostomy tube is removed with feculent material draining from the nephrostomy site.[110] Some investigators recommend antegrade nephrostogram at the end of the procedure to evaluate for colonic perforation.[101]

In the majority of cases, colon injuries can be managed conservatively if the perforation is retroperitoneal and the patient does not have signs of sepsis or peritonitis (Fig. 28.6).[101,111] An indwelling ureteral stent and Foley catheter should be placed and the nephrostomy tube should be pulled back into the colon, although some have suggested that placement of an indwelling ureteral stent may not be necessary and withdrawal of the nephrostomy tube into the colon is sufficient.[100] The patient should be administered broad-spectrum antibiotics and placed on a low-residue diet. A contrast study should be performed through the colostomy tube in 7 to 10 days, and the tube should be removed if no evidence of nephrocolic fistula is noted.[112,113] Open surgical management is required in patients with transperitoneal perforation, peritonitis, or sepsis and in those in whom conservative management has failed. Delay in diagnosis may increase the need for open surgical management.[101]

SMALL INTESTINE

The second and third portions of the duodenum are adjacent to the lower pole and pelvis of the right kidney and may be injured during PRS, although this complication is very uncommon.[114] Such an injury may occur during percutaneous access, if the renal pelvis is perforated during dilation, during placement of the working sheath, or during stone removal or tumor excision. This complication should be suspected if intestinal mucosa and contents are visualized, and it is usually diagnosed when contrast material is seen in the duodenum during intraoperative or postoperative nephrostogram. Surgical exploration is required in the majority of cases, specifically with large perforations or in patients with signs of sepsis or peritonitis. Patients with small injuries who are clinically stable can be managed conservatively. Conservative management includes antibiotics, nasogastric suction, and parenteral hyperalimentation. The nephrostomy tube should be positioned correctly in the collecting system to ensure adequate drainage or withdrawn into the bowel lumen with separate urinary drainage. A nephrostogram and an upper gastrointestinal radiograph study are performed 10 to 14 days following the injury to assess for closure of the fistula.

LIVER, GALLBLADDER, AND SPLEEN

The liver is rarely injured during PRS. Hopper and Yakes studied the relationship between the liver and kidney and reported on the risk of liver injury with different access approaches.[92] These investigators reported that the risk of injury with an 11th–12th rib intercostal approach was minimal. The risk increased to 14% for a 10th–11th rib approach during inspiration. Hepatomegaly increases the risk of injury to the liver, and for these patients, CT-guided access should be considered to minimize this risk. If injury to the liver is diagnosed postoperatively, the nephrostomy tube should be left in place for 7 to 10 days to allow for maturation of the tract. After this time, the tube can be carefully removed, but if high-volume bleeding is noted, the tube should be reinserted immediately. Additionally, fibrin products can be instilled through the tract to improve hemostasis. Retrograde placement of an internalized ureteral stent at the time of nephrostomy tube removal may aid in preventing the development of a renobiliary fistula. Injury to the gallbladder can also occur during access, with similar risk factors to liver injury. Patients present with signs of peritonitis with or without septic shock, are typically diagnosed during laparoscopy/laparotomy, and treatment consists of cholecystectomy in all cases.[106,115]

Splenic injury is very uncommon during PRS, likely because of the spleen's cephalad position.[116,117] Hopper and Yakes also analyzed the relationship between the kidney and spleen and noted that the spleen should not be at risk of being traversed with an 11th–12th rib supracostal approach during expiration, but the risk during inspiration was 13%.[92] This risk increased to 33% when a 10th–11th rib approach was used. In patients with splenomegaly, the risk is even higher. Injury to the spleen can cause significant internal bleeding and, in some cases, hypovolemic shock. The diagnosis is established with CT or US. Although some patients with splenic laceration can be managed nonoperatively (with bedrest, maintaining tube tamponade, close hemodynamic monitoring, and rarely splenic embolization), most patients require splenectomy.[1,2,106,117]

LYMPHATICS

Perforation of the collecting system during PRS may cause disruption of adjacent lymphatics that could lead to chyluria.[118] Management of this complication consists of optimizing urinary drainage and maintaining the patient with total parenteral hyperalimentation until the chyluria resolves. If this occurs in a delayed fashion, a low fat, medium-chain triglyceride diet can be trialed. Somatostatin may aid in the treatment of these cases.[119] If chyluria persists, sclerotherapy can also be attempted with retrograde instillation of silver nitrate or povidone-iodine.[120,121] For further refractory cases, renal pedicle lymphatic ligation can be performed.[122,123]

Medical Complications

INFECTION AND SEPSIS

It is mandatory for all patients with urinary tract infections to be treated with the appropriate antibiotic therapy before they undergo PRS because of the risk of bacteremia and sepsis from the extravasation of bacteria into the pyelovenous or pyelolymphatic channels. Antibiotic therapy for patients with urinary tract infections should be initiated at least 1 week before the procedure. The use of prophylactic antibiotics in patients with sterile urine culture is controversial, although many urologists will similarly place patients on 1 week or more of preoperative antibiotic prophylaxis despite a negative urine culture. Mariappan and associates reported on the use of prophylactic antibiotics in patients with stones >2 cm or pelvicalyceal dilation with negative urine cultures.[124] These investigators found that in these patients, prophylaxis with 1 week of ciprofloxacin significantly decreased the risk of urosepsis after PRS; similar results were found with nitrofurantoin prophylaxis in subsequent studies.[125] Other studies comparing patients with negative preoperative urine culture who received either single-dose antibiotics in the operating room or continuation of antibiotics until the nephrostomy tube was removed found no difference in rates of postoperative fever, bacteriuria, or bacteremia.[126–129]

Negative preoperative urine cultures do not preclude patients from developing bacteremia or urosepsis. Rao and colleagues demonstrated that patients without bacteriuria may still develop bacteremia and endotoxemia.[130] This is likely because negative urine culture results do not predict negative pelvic urine or stone culture results.[131] Margel and colleagues found that 25% of patients with a negative urine culture result had a positive stone culture result.[132] In these patients, the most common organisms found in the stone culture were gram-positive organisms; *Enterococcus* was reported in 42% of the cultures. In another study, Mariappan and colleagues found that bladder urine culture results were positive in only 5.6% of patients, whereas 42.6% of patients had positive results of pelvic urine or stone cultures.[133] These investigators also found that positive results of pelvic urine and stone cultures were associated with a significantly greater risk for urosepsis than were positive results of bladder urine cultures. It has been shown that stone culture results more frequently correlate with the causative pathogen in the setting of postoperative urosepsis when compared to preoperative urine culture.[134] It is important to send renal pelvis urine and stone for culture during PCNL to help predict and guide therapy in the event of urosepsis.

Multiple studies have attempted to qualify which patients are at increased risk for postoperative urosepsis given preoperative parameters to better guide the use of antibiotic prophylaxis. In addition to the aforementioned positive urine and stone cultures, studies have also pointed toward increased stone burden, history of recurrent urinary infections, and urine cultures with multidrug-resistant bacteria as risk factors for postoperative urosepsis.[135–137]

Purulent urine may be unexpectedly encountered at the time of accessing the collecting system. When this occurs, it is sensible to delay treatment, leave a nephrostomy tube in place to drain the collecting system, culture the fluid, and give the patient appropriate antibiotic therapy. Even with these precautions, patients can still develop urosepsis when the stone is eventually treated.[138]

Sepsis has been reported in 0.6% to 1.5% of patients undergoing percutaneous stone removal, which can be secondary to bacteremia and/or endotoxemia.[1,2,53] Patients should be monitored closely after surgery for signs or symptoms of systemic infection, including changes in vital signs, mental status, and laboratory values. Although postoperative leukocytosis and fevers are common, significant elevations in these values may be a sign of postoperative sepsis in patients after PRS; other tests such as lactate levels and procalcitonin may assist in early diagnosis of postoperative sepsis.[139–141] These patients should be aggressively managed with antibiotic therapy and fluid resuscitation, as well as with other supportive measures such as steroids and pressors. If the patient does not respond to these measures, CT imaging is recommended to assess for injury to adjacent structures or other complications that could be contributing to the sepsis. Fungal urosepsis should be considered in patients who are at risk, such as those who are immunocompromised or diabetic or who have had prolonged ureteral stenting.[142] Additionally, patients who are appropriately managed with pre/perioperative antibiotics may still suffer from postoperative systemic inflammatory response syndrome (SIRS)/sepsis due to endotoxemia, which similarly will require supportive measures such as fluid resuscitation, close monitoring, and possibly pressor support.

FLUID OVERLOAD

Irrigating fluid can be absorbed during PRS. Collecting system perforation and bleeding have been shown to increase the amount of fluid absorbed significantly.[143] Careful intraoperative monitoring of the input and output of irrigating fluid can help detect this problem. Signs of fluid absorption and subsequent fluid overload include unexpected hypertension and hypoxemia. Maintaining the lowest irrigation pressure that permits visibility can minimize fluid absorption. The use of a working sheath can reduce pressure in the pelvicalyceal system and thereby can reduce fluid absorption.[143] Limiting the duration of the procedure and discontinuing the procedure in the setting of significant collecting system perforation also reduce this complication. Normal saline solution should be used as an irrigant whenever possible to limit the development of hyponatremia. The administration of diuretics may be required for managing the hypervolemic patient with signs of fluid overload.

HYPOTHERMIA

Core body temperature has been shown to decrease during PRS. Hypothermia, defined as core body temperature <36°C, may occur. Decrease in core body temperature is multifactorial, and causes include vasodilation secondary to anesthesia, length of the procedure, exposed body surface, low room temperature, and the use of room temperature or cold irrigant. The consequences of hypothermia include impaired platelet function, altered enzymatic drug clearance, and shivering leading to significantly increased oxygen consumption. Increased oxygen consumption combined with decreased oxygen delivery can lead to cardiac ischemia or arrhythmias. Measures such as the use of warmed irrigant, proper patient coverage, use of heat-preserving drapes, and keeping patients as dry as possible can help reduce the risk of hypothermia.[144,145]

POSITIONING-RELATED INJURIES

Proper positioning of patients undergoing PRS is essential. Patients are typically placed in the prone position, and injuries to the brachial plexus and other peripheral nerves, shoulder dislocation, and cutaneous skin trauma can occur. All pressure points should be padded, and patients should be positioned to avoid strain on joints. If neurapraxia is suspected, prompt neurologic evaluation is warranted. Most of these injuries resolve over time with conservative treatment such as physical therapy.

Some groups have advocated that PCNL should be performed with patients in the supine position.[146,147] One concern of performing PRS in the supine position is the potential increased risk of damaging adjacent organs, particularly the colon. Multiple studies and meta-analyses have been performed in recent years to compare supine lithotomy positioning to traditional prone positioning. Results have been inconsistent, but most recent studies show a similar postoperative complication rate, similar hospital stay, and similar operative times; supine PRS may lead to slightly lower stone-free rates.[148,149] One such study did note an improvement in intraoperative anesthesia parameters during supine PRS, including heart rate, blood pressure, and peak airway pressures, although the long-term clinical significance of this is unknown.[150] However, a recent study by Siev and associates demonstrated that peak inspiratory pressures did not increase or have significant change from the supine to prone position in both the nonobese and obese patients.[151] Manohar and colleagues demonstrated that the supine position can be used safely and effectively in obese and high-risk patients for PCNL.[147] US proved to be useful aiding in and obtaining access in these reports.

AIR EMBOLISM

Air embolism has been reported during PRS.[152,153] This complication can occur after air is injected into the collecting system to help delineate the anatomy or as a result of airflow reversal in an ultrasonic lithotripter, although Lipkin and colleagues reported on over 150 cases of air pyelograms without a single case of embolism.[154] Intraoperative signs of air embolism include hypoxemia, bradycardia, fall in end-tidal carbon dioxide, and even cardiopulmonary arrest. Other causes should be excluded, and intraoperative diagnosis can be made with echocardiography. Management includes cessation of the procedure and placing the patient in the left lateral decubitus position with the head and thorax tilted downward. A central venous access line can be placed to attempt to aspirate the air. Patients may require close postoperative monitoring, inotropic support, supportive care, and – in certain cases with concern for cerebral involvement – hyperbaric oxygen therapy.[155]

DEEP VEIN THROMBOSIS AND PULMONARY EMBOLISM

Deep vein thrombosis has been reported to occur in 1% to 3% of patients undergoing PRS.[53,156] Thromboembolic disease prevention stockings and sequential compression devices help to minimize the risk of deep vein thrombosis. Early postoperative ambulation should be encouraged to help decrease the risk as well. If postoperative deep vein thrombosis does occur, treatment is aimed at preventing propagation of the thrombus and embolic events.[157] Treatment usually consists of anticoagulation, although in the immediate postoperative period bleeding is often a concern. In these patients, an inferior vena cava filter may need to be placed. However, in patients with a mature nephrostomy tract, anticoagulation is usually well tolerated.

MORTALITY

Postoperative death is extremely rare in association with PRS. The mortality rate is reported to be 0.2%.[158] Most reported deaths were caused by myocardial infarction or pulmonary embolism, and this complication occurred in high-risk patients. Careful preoperative evaluation and patient preparation are critical to preventing mortality. In patients who are at high risk, intraoperative invasive monitoring and postoperative cardiac monitoring can help prevent mortality by allowing for early diagnosis of any concerning abnormalities.

LOSS OF RENAL FUNCTION

The effects on renal function from PRS are believed to be minimal. Reports of imaging studies before and after PRS have demonstrated small parenchymal scars at the tract site.[159,160] Chatham and colleagues evaluated patients before and after PCNL with technetium-99m mercaptoacetyltriglycine nuclear renography.[161] These investigators demonstrated stable or improved renal function in 84% of patients and deterioration of function in 16%, although other studies did suggest focal decrease in function at the access site.[162] Handa and associates found a significant increase in serum creatinine of 0.14 mg/dL 1 day after PRS, which was also shown to normalize at approximately 72 hours postoperatively.[163,164] Further studies have isolated ipsilateral and contralateral renal response to PRS and have shown a bilateral decrease in creatinine clearance, with the ipsilateral renal unit showing a more severe response; this injury also appeared to resolve within 72 hours.[165]

Studies have demonstrated no significant change in serum creatinine concentration over the course of 1–2 years after PRS in patients with normal and impaired renal function.[166,167] Using nuclear renography, Dawaba and colleagues evaluated renal function in children undergoing PCNL and found a stable selective glomerular filtration rate (GFR) in 52.8% of renal units, an increase in GFR in 41.7% of renal units, and a decrease in GFR in 5.6% of renal units.[168]

Patients with staghorn calculi are unique in their increased risk of renal function deterioration. Teichman and colleagues reported that 25% of patients with staghorn calculi treated with PRS had a decrease in renal function.[169] These investigators cited solitary kidney, recurrent calculi, hypertension, complete staghorn calculus, urinary diversion, and neurogenic bladders as further risk factors for functional deterioration in this group, which has been seen in other series as well.[170,171] These findings support the idea that the functional deterioration in this group of patients is not likely to be procedurally related, but rather the result of their stone disease and comorbidities. Additionally, though, the effect of multiple access tracts on renal function has been recently questioned.[170]

Acute renal loss is very uncommon following PRS. It is usually secondary to uncontrollable hemorrhage. The incidence has been reported to be between 0.1% and 0.3%.[53,172] The long-term risk of renal loss has been estimated to be 1.6% in patients who have had staghorn calculus treated with PRS.[173]

Conclusions

PRS is associated with a variety of complications. These include, but are not limited to, hemorrhage, injury to the collecting system and kidney, injury to adjacent organs, infection or sepsis, and even death. Appropriate patient selection, possibly with assessment of functional status, and preoperative workup can help minimize these complications.[174] Patient counseling preoperatively (both with discussion and handwritten and/or online educational material) will also allow for patients to understand the complexity of the surgery and help in establishing expectations for the postoperative period. Surgical technique plays a large role in preventing complications, and care must be taken during each step of the procedure. An experienced surgeon will be able to minimize the risks of this complex procedure; increased caseloads have been demonstrated to decrease the complication rates of PRS.[175] Prompt recognition of problems is critical when they occur; most complications can be managed conservatively.

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Chapter 28 Questions

1. During percutaneous access after using an air retrograde pyelogram for percutaneous nephrolithotomy for large right-sided intrarenal stones, the patient becomes hypoxemic and bradycardic. What is the next step in treatment?
   a. Completion of the lithotripsy and stone removal and transfer to the intensive care unit
   b. Cessation of the procedure and placement of the patient in left lateral decubitus position with head tilted downward
   c. Attempt to withdraw air from the renal collecting system with suctioning of the 5Fr open-ended catheter
   d. Immediate cessation of the procedure, placement of pacer pads, and initiation of defibrillation
   e. Immediate placement of chest pigtail catheter or chest tube

2. The response of a patient's renal function after percutaneous renal surgery includes:
   a. Focal renal function increasing at the site of access
   b. A decrease in overall serum creatinine after percutaneous nephrolithotomy
   c. A permanent increase in overall serum creatinine between 2 and 5 years after percutaneous nephrolithotomy
   d. A decrease in creatinine clearance of bilateral renal units after unilateral percutaneous nephrolithotomy
   e. A smaller functional decline after percutaneous nephrolithotomy in renal units with staghorn calculi

3. If post-percutaneous nephrolithotomy chyluria persists after conservative management with dietary measures and somatostatin, the next step in management should be:
   a. Lymphangiography and embolization of the cisterna chili
   b. Urgent nephrectomy
   c. Retrograde sclerotherapy with silver nitrate or povidone-iodine
   d. Angiography and embolization of the affected kidney
   e. Antegrade drainage with nephrostomy tube placement

4. Regarding positioning for percutaneous nephrolithotomy:
   a. Prone-flexed positioning may provide improved access to the upper pole
   b. Supine positioning increases peak airway pressures during percutaneous nephrolithotomy compared to other methods
   c. Typical prone placement puts patients at high risk for brachial nerve injury
   d. Supine position is a significant risk factor for intraoperative colonic injury
   e. Studies show that supine position is not safe for obese patients

5. Which of the following methods will decrease intraoperative blood loss during percutaneous renal surgery?
   a. Access into a posterior calyx perpendicular to the infundibulum
   b. Use of flexible nephroscopy or additional access tracts for staghorn stones
   c. Frequent manipulation of working sheath during the procedure
   d. Use of a larger working sheath during access
   e. Positioning of the working sheath within the renal parenchyma

6. Two days postoperatively from a percutaneous nephrolithotomy, the patient's fever spikes at 102.5°F and she becomes hypotensive and tachycardic. After workup including CT scan, the nephrostomy tube is found to be passing through the colon via a transperitoneal path. The patient becomes unstable at this point; the next step in management is:
   a. Withdrawal of the nephrostomy tube into the colon and placement of an internalized ureteral stent and Foley catheter
   b. Broad-spectrum antibiotics and observation
   c. Urgent open exploration and repair
   d. Placement of a second nephrostomy tube by interventional radiology via a retroperitoneal approach
   e. Nasogastric suction and parenteral nutrition

7. During the initial access for percutaneous nephrolithotomy, significant bleeding is noted. All of the following are suggested methods for managing such intraoperative hemorrhage except:
   a. Urgent transfusion and continuation of the procedure
   b. Ensuring proper position of the sheath within the collecting system
   c. Reinflation of the dilation balloon to tamponade the injured vessels
   d. Placement and clamping of a large-bore nephrostomy tube
   e. Administration of mannitol to induce renal swelling within the capsule

8. Extraureteral stone fragments most commonly result in:
   a. Fibroepithelial polyp formation
   b. Ureteral stricture formation
   c. Recurrent UTIs
   d. Chronic flank pain
   e. No clinical symptoms

9. What is the reported incidence of upper tract stricture after percutaneous renal surgery?
   a. >10%
   b. 5–10%
   c. 2–5%
   d. 1–2%
   e. <1%

10. While the optimal preoperative antibiotic prophylaxis regimen is undetermined at this time, certain risk

factors for postoperative urosepsis have been demonstrated. All of the following factors are associated with urosepsis except:
a. Positive renal pelvis urine cultures
b. Increasing stone burden
c. History of multidrug-resistant bacteria in the urine
d. Lack of antibiotic administration until nephrostomy tube removal
e. Positive stone culture

Cases Studies

CASE 1

A 47-year-old man is undergoing right percutaneous nephrolithotomy for a 2.5-cm renal pelvis stone. Based on the patient's renal anatomy, it is determined that an upper pole access point would allow for the best approach to the stone. Preoperative imaging previously delineated the expected location of the accessible calyces, and access is achieved in a supracostal manner.

1. Based upon the access site, the patient is at increased risk for all of the following except:
   a. Pleural entry
   b. Hydrothorax
   c. Laceration of intracostal vessels
   d. Hepatic injury
   e. Lymphatic disruption

After access is achieved, the stone is reached and fragmented in the typical fashion. The case proceeds as expected, and at the conclusion of the procedure, a stent and nephrostomy tube are placed for drainage of the collecting system. Prior to waking the patient from anesthesia, chest fluoroscopy is performed, and a very small right-sided hydrothorax is noted. Anesthesia notes normal saturations, peak ventilation pressures, and tidal volumes.

2. The next step for this patient is:
   a. Emergent thoracotomy
   b. Tube thoracostomy for drainage of hydrothorax
   c. Placement of tube through the nephropleural tract for drainage
   d. Extubation and postoperative observation for respiratory compromise
   e. Continued intubation and transfer to intensive care

The decision is made at this time to observe the patient for his small asymptomatic hydrothorax. He does well over the morning of his first postoperative day with stable labs, pain controlled, and adequate ambulation. A few hours later the patient is noted to have increased work of breathing, decreased oxygen saturation, and increased right-sided chest pain with inspiration. Chest imaging shows an enlarging hydrothorax compared to his initial fluoroscopy.

3. The next step in management for this patient is:
   a. Thoracoscopy for formal diagnosis and treatment
   b. Tube thoracostomy for drainage of hydrothorax
   c. Urgent nephrostogram to evaluate for nephropleural fistula
   d. Observation
   e. Instillation of silver nitrate into the nephrostomy tube to sclerose the pleural injury

CASE 2

A 54-year-old man is scheduled to undergo percutaneous nephrolithotomy of a left renal stone. While discussing surgery with his urologist prior to his operative day, he requests information regarding different positioning options for the operation, as he has heard that the procedure can be performed in many different positions.

1. Which of the following has been considered a benefit of supine positioning for percutaneous renal surgery over traditional prone position?
   a. Ease of simultaneous antegrade and retrograde access
   b. Lower risk of postoperative infection
   c. Higher stone-free rates
   d. Significantly lower risk of colonic injury
   e. Shorter hospital stay

The procedure is performed in a supine-lithotomy position. After approximately 85% of the stone is fragmented, an area of perirenal fat is noted on rigid nephroscopy, consistent with a perforation of the collecting system. At this point, the patient's flank is noted to be more distended than prior, although he continues to ventilate well.

2. What is the next step in management for this patient?
   a. Endoscopic evaluation of the point of perforation with flexible retroperitonoscopy using a flexible ureteroscope
   b. Conversion to open nephrectomy
   c. Placement of an additional access point
   d. Prompt termination of the procedure with low-flow irrigation, placement of a nephrostomy tube, and nephrostogram at 1 week to ensure closure of the perforation
   e. Endoscopic cauterization of the perforation

Two months after his initial surgery, after all tubes were removed and complete closure of the perforation was documented on imaging, the patient returns to the emergency room with new-onset fevers, left flank pain, and elevated WBC count. Urographic imaging shows an obstructed upper pole calyx without an obstructing stone concerning for infundibular stenosis.

3. The next step in management for this patient is:
   a. Urgent cystoscopy and stent placement
   b. Tube thoracostomy placement to improve ventilatory status
   c. Nephrostomy tube placement with eventual antegrade or retrograde treatment to open the stenotic area
   d. Upper pole hemi-nephrectomy
   e. Observation

Answers

1. **b.** When there is intraoperative clinical concern for air embolism, the first step in management is to place the patient in a left lateral decubitus position to decrease the risk of air lock within the right heart, which can be a cause of ventricular obstruction and death.
2. **d.** Differential studies have shown that bilateral renal units have a negative response to PRS, with the ipsilateral kidney demonstrating a more severe reaction. This injury appears to resolve by 72 hours.
3. **c.** Small studies have found a good response rate with retrograde instillation of silver nitrate and povidone-iodine for sclerotherapy of the lymphatic fistula, although conservative management should be attempted as above prior to such a procedure.
4. **a.** Patients placed in a prone-flexed position have a caudal displacement of the kidney with decreased need for supracostal access, which enables easier access to the upper pole.
5. **b.** The use of flexible nephroscopy and additional access tracts can decrease intraoperative blood loss compared to inappropriate torqueing of the rigid nephroscope. Calyceal access should occur parallel to the line of its infundibulum to decrease risk of parenchymal injury. Manipulation of the sheath, use of a larger sheath, and improper positioning of the sheath all will increase risk of blood loss.
6. **c.** While inadvertent colonic injury during percutaneous access can often be managed conservatively by withdrawing the nephrostomy tube into the colon, placement of a ureteral stent, and broad-spectrum antibiotics, once a patient shows signs of instability urgent open exploration and repair are required.
7. **a.** When significant bleeding is noted during the access for PRS, the initial response should include an assessment of the operative factors that may be contributing to the hemorrhage. This includes ensuring positioning of the sheath and performing maneuvers to tamponade the bleeding. The hemorrhage should not be ignored with transfusion and continuation of the procedure, as the source of the bleeding will likely continue throughout the surgery and needs to be addressed.
8. **e.** Evans and Stoller performed a retrospective review of cases associated with extraureteral stone fragments and found a minimal rate of complications.
9. **e.** The reported incidence of stricture after percutaneous renal surgery is noted to be extremely low – less than 1%.
10. **d.** Multiple studies have noted that antibiotics given at the time of nephrostomy tube removal result in no significant change in infection risk compared to antibiotics given from surgery until nephrostomy tube removal. Postoperative urosepsis has been linked to positive renal pelvis urine and stone cultures, increasing stone burden, and a history of multidrug-resistant bacteria in the urine.

CASE 1

1. **e.** Patients who undergo supracostal access are at an increased risk of pleural entry, hydrothorax, laceration of intracostal vessels, and hepatic injury. There has not been a documented risk increase for lymphatic disruption.
2. **d.** A small hydrothorax can initially be managed conservatively with oxygen supplementation and observation, as they often resolve spontaneously. If they persist or become symptomatic, additional therapies can be employed.
3. **b.** In patients who have worsening/symptomatic hydrothorax after PRS, drainage of the fluid is beneficial with tube thoracostomy. Persistent thoracic fluid after proper drainage with tube thoracostomy may signify nephropleural fistula, although this is an uncommon complication.

CASE 2

1. **a.** Proponents of supine positioning cite the ease of simultaneous antegrade and retrograde access for treatment of the stone, while none of the other options has been proven to be associated with this surgical position.
2. **d.** When intraoperative collecting system perforation is suspected, as in this case, the amount of fluid allowed to extravasate into the retroperitoneum should be minimized. This is done by terminating the procedure as rapidly as possible with low-flow irrigation. Additionally, a nephrostogram should be performed postoperatively to ensure resolution of the perforation.
3. **c.** Given the presentation of infection and obstruction, the best initial treatment for this patient would be placement of a nephrostomy tube into the obstructed calyx to allow for prompt drainage. Once the infection is fully cleared, infundibulotomy should be performed in either a retrograde or antegrade fashion to allow drainage from the obstructed calyx and prevent similar episodes in the future.

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29 Complications of Extracorporeal Shock Wave Lithotripsy

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CHAPTER OUTLINE

Hematoma
Steinstrasse
Sepsis
Cardiac Arrhythmias
Vascular Injury
Adjacent Organ Injury
Urinary Fistulas
Hypertension
Renal Insufficiency
Diabetes Risk
Fertility Effects
Potential Long-term Complications
Strategies to Reduce Risk of Complications
Conclusions
Chapter 29 Questions and Answers

KEY POINTS

1. Hypertension, especially poorly controlled, is a risk factor for post–extracorporeal shock wave lithotripsy (ESWL) hematoma.
2. Steinstrasse is often asymptomatic and resolves with observation. Active management depends on the patient's clinical status and the presence of sepsis or renal deterioration.
3. Antibiotics are not recommended for uncomplicated routine cases with sterile preprocedure urine. Sepsis is more common after ESWL of infection stones.
4. Cardiac arrhythmias are associated with ungated ESWL, and they usually spontaneously revert with gating.
5. Pulmonary injuries are seen mostly in children and can be prevented by prophylactic padding of the torso.
6. Although gastric and duodenal erosions are common, gastrointestinal injuries requiring intervention are extremely rare.
7. ESWL as the cause of new-onset hypertension remains controversial. It may be more common in older patients and those who have undergone bilateral procedures.
8. Reducing shock wave frequency to 60 shocks/min, stepwise voltage ramping, and brief treatment pause all serve to reduce risk of renal injury.

Extracorporeal shock wave lithotripsy (ESWL) has revolutionized nephrolithiasis management since being introduced in 1980 by providing effective noninvasive treatment in an ambulatory setting. The energy that causes stone fragmentation can also injure renal tissue and surrounding structures. Fortunately, serious complications are rare. The complications and prevention strategies are reviewed in this chapter.

Hematoma

The delivery of shock wave energy to the kidney results in some degree of acute renal injury, including interstitial bleeding and disruption of small to medium renal arteries and veins.[1,2] While transient gross hematuria is frequently seen post treatment, ESWL may also result in intrarenal bleeding (hematoma), which may extend into the perinephric tissue. Hematoma may be commonly detected on post-treatment imaging, but it is rarely clinically significant.[3–6] Fig. 29.1 shows a computed tomography (CT) image of a perirenal hematoma that developed after ESWL.

The reported incidence of renal hematomas varies between 0.28% and 4.1% in large series.[3–6] The most common risk factor is hypertension, especially when poorly controlled. Knapp et al. reported a 0.66% overall incidence of hematoma after ESWL: a 2.5% incidence for patients with well-controlled hypertension versus 3.8% for patients with poorly regulated hypertension.[7] Other risk factors include older age, obesity, diabetes mellitus, clotting disorders, vascular disease,[4,8,9] oral corticosteroid therapy, arteriosclerosis, impaired renal function, increasing stone density and urinary obstruction at the time of intervention.[10–14]

Clinical signs of hematomas include intense flank or abdominal pain, tachycardia, hypotension, and anemia. Hematomas generally are self-limited, and patients respond to supportive measures such as hydration, analgesics, and transfusion. Intervention is rarely necessary and renal loss

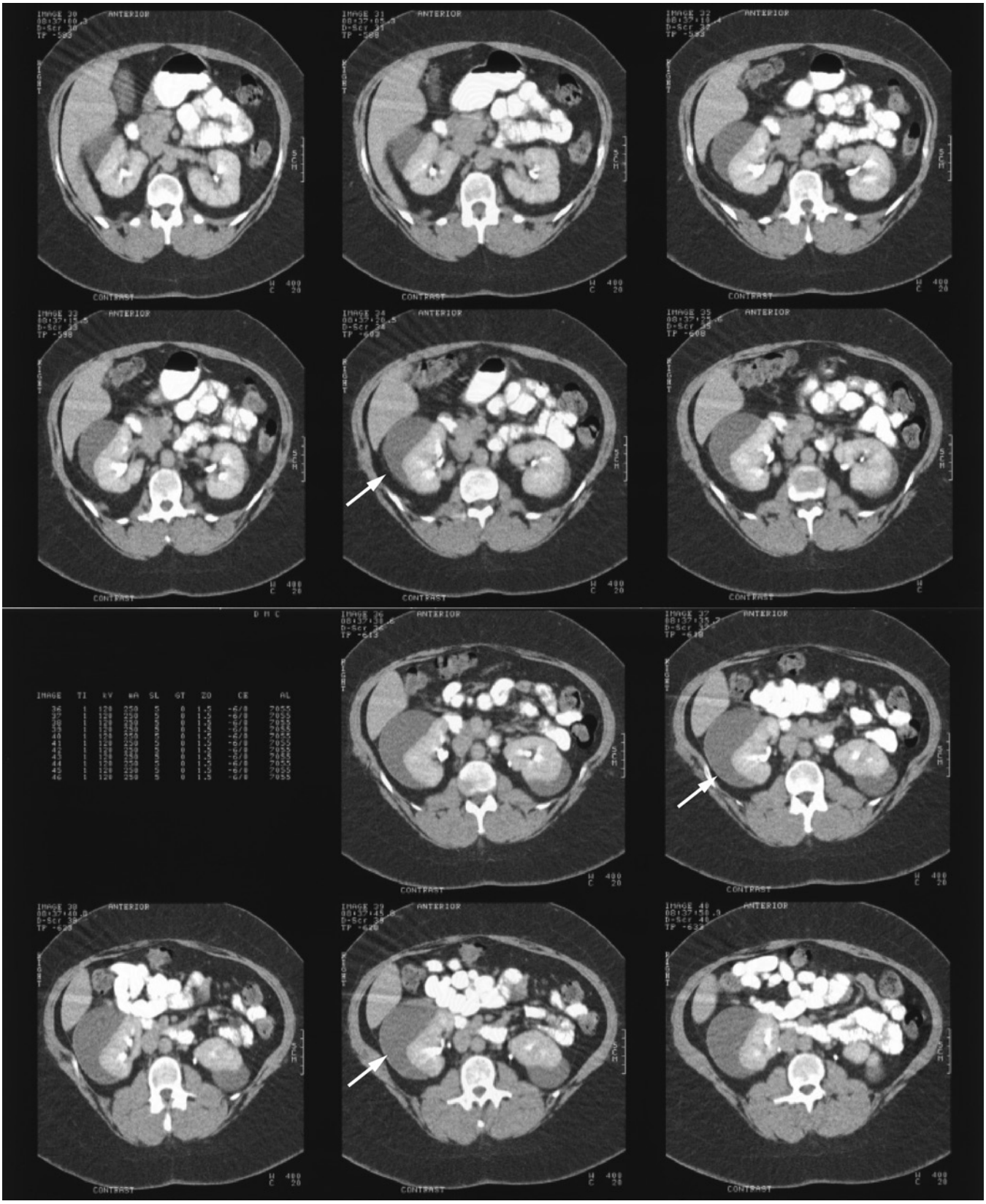


Figure 29.1 A CT scan of a right perirenal hematoma *(arrows)* after ESWL.

or death is exceedingly rare.[3–6,15] Upper tract imaging (CT, magnetic resonance imaging [MRI], or ultrasonography) can be performed to establish the diagnosis when required.

Most hematomas resolve spontaneously over time. In a study of 19 patients with 21 post-ESWL hematomas followed up to 5 years (mean follow-up 19.6 months), 85.7% of the hematomas completely resolved, 9.5% became smaller, and 4.8% did not change size. No patient without preexisting hypertension became hypertensive.[16] However, another study found that 36% of post-ESWL hematomas remained at 18 months after ESWL.[3] Page kidney is a rare cause of hypertension due to renal parenchymal compression from a hematoma.[17–19] Very rarely, incision of Gerota's fascia to decompress a hematoma is an option for large hematomas that significantly impair renal tissue perfusion causing Page kidney. A retrospective review of this practice did not reveal a difference in outcomes with regard to long-term impairment of renal function.[20]

Hematomas can be prevented by using shock wave energy judiciously and ensuring well-controlled blood pressure and absence of coagulation or platelet functional disturbances. Administering a small number of lower energy shock waves (voltage ramping) to the kidney before delivering therapeutic energy doses has been shown to dramatically attenuate hemorrhagic injury in an animal model.[21] It is hypothesized that the initial lower energy shock waves induce vasoconstriction and thus limit the injury.[22] This finding has been confirmed in a large randomized trial published in 2015 where stepwise voltage ramping reduced renal injury, including hematomas.[23]

Another common concern is perioperative anticoagulant management of ESWL patients. Few guidelines on management of thrombotic risk while undergoing ESWL exist, and data are largely retrospective and of poor quality.[24] For example, there is only one human study of aspirin use with ESWL.[25] Potential bleeding risk with ESWL must be balanced with thrombotic risk specific to the patient. In a review by Bourdoumis et al.[26] anticoagulants are stopped 5 days prior to surgery with bridging therapy as required. However, antiplatelet agents, including aspirin, are stopped at least 7 days prior. If the thrombotic risk is judged too high to stop anticoagulants, ureteroscopy is preferred due to higher ESWL complications and lower efficacy in this setting.[27] Patients on anticoagulants warrant perioperative risk stratification and multidisciplinary consult between anesthesia, urology, and cardiology services.

Steinstrasse

Steinstrasse, the accumulation of stone fragments in the ureter after ESWL, usually occurs in patients with larger stones, typically >2 cm. Almost three-quarters of large Steinstrasse occur in the distal portion of the ureter.[16] The reported incidence varies between 2% and 10%.[28–31] An x-ray image of right proximal Steinstrasse is seen in Fig. 29.2. Patients may have symptoms such as flank or abdominal pain, nausea, and emesis, although many are asymptomatic. Weinerth et al. reported that 5 of 19 patients with *large Steinstrasse* (defined as stone fragments occupying greater than one-third of total ureteral length) were asymptomatic.[32] The occurrence of Steinstrasse can be reduced by carefully selecting patients and choosing alternative treatments for patients with stones >2 cm.[31,32]

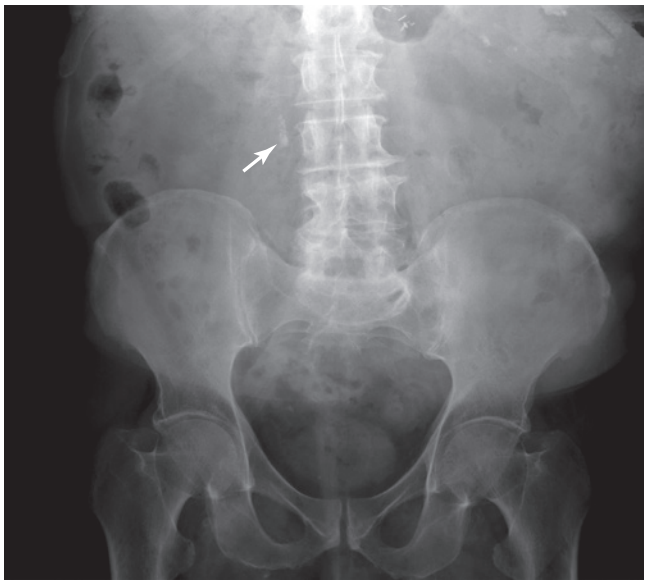


Figure 29.2 An x-ray image of right proximal Steinstrasse (arrow) after ESWL.

Patients with minimal symptoms, adequate renal function, and no signs of sepsis can be managed conservatively as 48% to 63% of Steinstrasse resolve spontaneously.[33,34] However, these patients need to be followed closely to ensure that the Steinstrasse does indeed resolve; otherwise renal function can be affected.

Patients with persistent Steinstrasse, ongoing symptoms, or complications (sepsis, renal impairment) require decompression. Percutaneous nephrostomy (PCN) is an option, with 75% of Steinstrasse passed solely with percutaneous nephrostomy insertion in one study.[35] PCN is especially useful in the setting of profound sepsis as it does not require general anesthesia with attendant hypotension risks. Ureteral stenting is another approach in an unwell patient not suitable for immediate ureteroscopy. Ureteroscopy for Steinstrasse is the definitive treatment with success rates approaching 100%, although it is not often required.[33,34] Repeat ESWL is another approach reported to be 80–90% successful.

The administration of α_1-blockers does not eradicate Steinstrasse. However, patients receiving such agents may have better pain control.[36] Preemptive ureteral stenting may prevent Steinstrasse in some patients with stones <3 cm, but it is ineffective for those with larger stones and is not associated with higher stone-free rates.[28,30] In addition, stented patients often have significant bothersome symptoms.[37] Finally, routine stent placement is not recommended for ureteral stones treated with ESWL.[38] An exception are patients with anatomically or functionally solitary kidneys where stent placement must be strongly considered.[39]

Sepsis

The overall risk of sepsis after ESWL is low at 1%[40,41] except in patients with preexisting treated or untreated urinary

tract infections (UTIs) and especially struvite stones. The risk of sepsis is higher in those with larger stones, especially staghorn calculi.[42] The urine in patients with larger stones more frequently contained endotoxin, which was associated with a higher risk of sepsis.[42,43] Positive preoperative urine culture, symptomatic UTI, indwelling stent, and nephrostomy tube increase the risk of fever post ESWL and warrant preoperative antibiotic therapy.[41] Patients suspected of harboring infection stones should receive broad-spectrum antibiotic therapy because there may be discordance between stone and urine cultures.[44] Despite sterile urine cultures before ESWL, bacteremia developed in 2.6% of those with struvite stones compared to 1.3% of patients with calcium stones.[45] An elevation of the inflammatory mediator C-reactive protein (CRP) has also been identified as a predictor of bacteremia.[45,46] Given the importance of complete clearance in infection and struvite stones, alternative treatment strategy such as PCNL or ureteroscopy should be considered in this setting.[47]

Prophylactic antibiotic administration to patients who have sterile pre-ESWL urine is controversial. A meta-analysis by Pearle and Roehrborn demonstrated significant decrease in the development of post-ESWL UTI in patients who received prophylactic antibiotics.[48] However, another meta-analysis by Lu et al. in 2012 argued against routine antibiotic prophylaxis in this setting.[49] Currently, routine uncomplicated ESWL cases with sterile pretreatment urine do not receive prophylactic antibiotics.

Cardiac Arrhythmias

Cardiac arrhythmias have been reported with both gated (shock delivery synchronized to patient electrocardiogram R-wave) and, more commonly, ungated ESWL. Gating was required with the original lithotriptor, the Dornier HM3, as the water bath allowed the unfocused portion of the shock wave, which expanded spherically from the aperture of the ellipsoid, to pass through the heart resulting in a very high incidence of ventricular arrhythmias. This problem is mostly eliminated with dry head lithotriptors. Zanetti et al. reported cardiac arrhythmia incidence of 8.8% among 269 consecutive patients without a history of cardiac arrhythmia who underwent ungated ESWL.[50] Although 59% of patients who developed arrhythmia converted back to normal sinus rhythm with temporary halting of shocks and remained so after resumption of ungated ESWL, 36% required gating to prevent arrhythmia recurrence and <1% (one patient) required atropine to manage persistent bradycardia. There was no correlation found with the side of treatment with ESWL, the number or strength of shocks, or the anesthetic agents delivered, although another study suggested right-sided renal stone ESWL is more likely to produce arrhythmia.[51]

Greenstein et al. reported asymptomatic premature ventricular contractions in 18.4% of 125 ungated ESWL procedures.[52] No correlations were found with age or gender of patient, presence of heart disease, size or location of stone, presence of ureteral catheter or nephrostomy, mode of anesthesia, and number of shocks delivered. Interestingly, arrhythmia was again seen more often during right-sided procedures.

The immediate postprocedure course of patients undergoing ungated ESWL was studied by Winters and colleagues. Of 82 patients, 21% developed arrhythmias. All but two arrhythmias were benign and all reversed with subsequent gating. No arrhythmias occurred with shock energies lower than 20 kV. No electrocardiogram changes were seen up to 1 hour after the procedures were completed.[53]

Gating and ungating during the same procedure were compared by Ounnoughene and colleagues. Twenty-five patients with no cardiac history underwent ESWL with shocks delivered both gated and ungated. During the gated phase, no arrhythmias developed. During the ungated phase, 7 of the 25 patients developed arrhythmias but all were asymptomatic, and the arrhythmias regressed spontaneously after the procedure was completed.[54]

A comparison of 3288 patients with and without a history of arrhythmia was performed by Cass. In this unique study, ungating was used in patients with known arrhythmias, and gating was used in patients without known arrhythmias. In the group with no known preexisting arrhythmias, one patient developed a malignant arrhythmia during the ungated procedure.[55]

These findings indicate that the development of cardiac arrhythmia is mainly associated with ungated ESWL. The consequences of cardiac arrhythmia appear minimal. Most arrhythmias are benign and resolve with gating, therefore, gating is advocated in the presence of arrhythmia. Of note, gating is not required in the pediatric population as the incidence of arrhythmias is low.[56,57]

Finally, cardiac pacemakers may need to be reprogrammed before ESWL treatment in consultation with cardiology service. The pacemaker should be at least 5 cm from the shock wave blast path.[58]

Vascular Injury

Rarely, bleeding secondary to ESWL can result in hemodynamic instability. This is an indication for embolization or even surgery.[12,59,60] Rupture of abdominal aortic aneurysms (AAAs) has been reported after ESWL.[61,62] However, it is not clear whether the shock wave energy per se promoted rupture. The impact of shock wave energy on atherosclerotic vessels has been assessed in an in vitro study with minimal histologic changes in aortic aneurysmal tissue post ESWL.[63]

There are reports of patients with smaller AAAs (<5.5-cm diameter) undergoing uneventful ESWL.[64] Patients with calcified renal artery aneurysms <2 cm in size and vascular grafts also have undergone successful ESWL.[65,66] One study suggests ensuring a minimal aneurysm to stone distance of 5 cm, with aneurysm not in parallel to the shock wave path.[65] However, given the potentially catastrophic consequences of aneurysm rupture, careful patient consultation is warranted.

Finally, there are reports of patients developing venous thrombosis in the portal vein, renal vein, and iliac veins after ESWL. However, the exact cause of the venous thrombosis could not be determined in these cases.[67–69]

Adjacent Organ Injury

Shock waves may traverse the lung parenchyma and inflict damage. There are reports of pulmonary contusion with ESWL,[70] which typically manifests with hemoptysis or hypoxemia. ESWL has produced blast injury in rat and rabbit lung models.[71,72] Children appear particularly susceptible to this type of injury, as the lung parenchyma is closer to the shock wave path, although it can occur in adults as well.[73] Styrofoam has been applied to the chest area of children, and air vests have been worn by children to prevent such occurrences, although data supporting the use are limited.[74]

Skeletal muscle can be traversed with shock waves during ESWL. Although studies have demonstrated increases in muscle-derived enzymes in the serum and urine of patients subjected to ESWL, we are unaware of any reports of clinically significant muscle damage or rhabdomyolysis after treatment.[75,76] In fact, shock wave energy may have beneficial therapeutic effects in patients suffering from certain musculoskeletal disorders such as plantar fasciitis and calcific tendonitis.[77,78]

A mild degree of hepatic injury is not uncommon after treatment of renal and proximal ureteral stones. Studies report increase in serum bilirubin, aspartate transaminase, and glutamate dehydrogenase (a marker for hepatocellular injury);[79,80] however, significant injuries such as subcapsular hematoma and hepatic fracture are extremely rare.[10,81–83] The signs of subcapsular hematoma and hepatic fracture include hypotension, tachycardia, anemia, abdominal pain, and ileus. Imaging studies (ultrasonography, CT, MRI) should be obtained if hepatic injury is suspected. Patients with subcapsular hematoma are observed closely, whereas an active intervention may be required if hepatic fracture has occurred.

A few cases of injuries to the spleen and pancreas have been reported in patients who received ESWL to treat renal stones, although these complications are rare. The manifestations vary and include abdominal pain, peritonitis, sepsis, and shock. Splenic injury is more common with treatment of the left renal unit, whereas pancreatic injury typically occurs after right-sided procedures. At least two cases of splenic rupture requiring splenectomy after treatment of an 18-mm left upper pole stone[84] and 2-cm left renal pelvis stone[85] have been reported. Infectious sequelae can also arise following splenic injury. Treatment of a left lower pole renal stone resulted in anemia, leukocytosis, and fever with an infected perisplenic hematoma requiring splenectomy and abscess drainage.[86] Although select patients with spleen and pancreas injuries from ESWL can be managed with observation, a death from anemia and sepsis with this wait-and-see approach has been reported.[87]

The pancreas also can be injured when ESWL is used to treat upper urinary tract stones. Pancreatitis has been reported after ESWL of renal calculi,[88] as have histologic changes of pancreatic injury.[89] As expected, the occurrence of pancreatitis is higher with ESWL of pancreatic duct stones, and more severe pancreatic injuries can occur.[90,91] Late presentation of pancreatic pseudocyst requiring open surgical correction 1 year after ESWL has also been reported.[92] Very rarely, hematomas of other organs, even thoracic spinal cord epidural hematoma, can occur.[93]

The stomach, duodenum, small and large bowel may be injured during ESWL. In a literature review, Maker and Layke found 10 reported bowel perforations in 3423 patients (0.34%) who underwent ESWL. There were six small bowel perforations, three colonic perforations, and one dehiscence of a gastrojejunal anastomosis. All 10 patients required open surgical correction.[94] Patients who are treated in the prone position may be at higher risk for this injury. A left ureterocolic fistula in a patient with an impacted stone was also noted in this review; the patient was treated with nephroureterectomy. An additional 12 patients had evidence of less severe injury not requiring surgery including ulcerations of the cecum, colonic hematoma, and hematochezia.[94] The potential for upper gastrointestinal injury with ESWL was assessed by Al Karawi and colleagues who performed esophagogastroduodenoscopy in 40 patients before and after ESWL. New gastric or duodenal erosions were identified in 32 (80%) after ESWL.[95] Although significant gastrointestinal complications are extremely rare, a high index of suspicion is warranted in any patient who develops peritonitis after ESWL. Prompt evaluation and treatment are mandatory.

There are reported cases of skin burns due to overheating of the water-filled acoustic coupling cushion.[96] Finally, ureteral strictures following ESWL for ureteral stones are very infrequent, ranging from 0% to 2% in one meta-analysis.[38]

Urinary Fistulas

There have been scattered reports of patients developing fistulas after ESWL, including pyelocutaneous, pyeloduodenal, ureterocolic, and ureterovaginal. The majority of these fistulas occurred in patients with staghorn stones or undiagnosed xanthogranulomatous pyelonephritis. Nephrectomy was undertaken in most of these cases. The primary renal problem was the most likely inciting factor in these cases.[94,97–102]

Hypertension

The issue of ESWL-induced hypertension remains controversial. This association was first reported in the late 1980s, and numerous conflicting studies have been published in subsequent years. The relevant studies are profiled in Table 29.1.[103–116]

Certain patient factors and treatment approaches have been demonstrated to be associated with the development of hypertension. Janetschek and colleagues reported that age >60 years was a risk factor for the development of new-onset hypertension. They also found that older age correlated with an increase in the renal resistive index measured with Doppler ultrasonography.[109]

In the study with the longest follow-up (19 years), Krambeck and associates reported that hypertension developed more commonly in ESWL-treated patients than in a case-controlled group of patients who had had stones but had not received ESWL. Patients subjected to bilateral ESWL were at higher risk for developing hypertension. However, risk of hypertension did not appear to relate to the number

Table 29.1 Reports of Hypertension and Extracorporeal Shock Wave Lithotripsy

Study	Length of Study (MO)	No. of Shocks Range	Mean	Change in Incidence of Hypertension	Change in Diastolic Blood Pressure
Liedl et al., 1989[103]	40	Not recorded	1043	No change	Not recorded
Williams et al., 1988[104]	21	800–2000	1400	Increased	Increased
Puppo et al., 1989[114]	12	1100–1900	1380	No change	No change
Montgomery et al., 1989[106]	29	110–3300	1429	Increased	No change
Lingeman et al., 1990[107]		Not recorded	1289	No change	Increased
Yokoyama et al., 1992[108]	19	1500–3000	Not recorded	Not recorded	Increased
Janetschek et al., 1997[109]	26	2600–3000	2735	Increased (60–80-year age group)	Increased (60–80-year age group)
Jewett et al., 1998[110]	24	Not recorded	4411	No change	No change
Strohmaier et al., 2000[111]	24			Increased	Increased
Elves et al., 2000[112]	26.4	Not recorded	5281	No change	No change
Krambeck et al., 2006a[113]	228	500–4500	1125	Increased	Not recorded
Eassa et al., 2008[115]	43.6	Not recorded	Not recorded	Increased	No change
Sato et al., 2008[116]	204	400–2300	928	No change	Not recorded

of shocks delivered or shock wave intensity.[113] Krambeck and associates also reported that those who received ESWL were more prone to developing diabetes mellitus and that there was a positive correlation to the numbers of shocks delivered and shock wave intensity, whereas the side of the involved renal unit had no influence. A review of 70 pediatric patients by El-Nahas over an average of 5 years' follow-up did not reveal evidence of hypertension or diabetes in this cohort,[117] although there was evidence of reduced renal growth post ESWL in children in another study.[118]

The literature review indicates that the association between ESWL and developing hypertension is not uniformly positive. This is at least partially due to study design and inadequate controls. In addition, hypertension is a multifactorial disease and association does not always equate with causation. Certainly, patients with renal calculi, as a group, are at a higher risk for developing hypertension.[119–123] From a clinical standpoint, the risk of blood pressure effects from ESWL is rarely relevant but might be considered in a patient with poorly controlled hypertension.

Renal Insufficiency

The kidney sustains a degree of acute injury from the received shock wave energy, in part due to cavitation and shear forces exerted.[124] The reduction in renal blood flow that occurs with delivery of shock wave energy to the kidney may produce renal ischemia, which could lead to renal injury.[125] Animal models have demonstrated that this results in the generation of oxygen free radicals, which may further promote injury.[125] Direct shock wave trauma also plays a role in acute renal dysfunction. Koga and colleagues examined canine kidneys after repeated ESWL treatments and positively correlated the degree of tissue hypoxia and rupture of interstitial capillaries with the number of shocks delivered.[126]

While stone formers are at risk of developing renal insufficiency (RI), there is no current evidence to suggest that ESWL promotes it. Krambeck and associates did not find increased rates of RI after long-term follow-up in patients treated with ESWL.[113] The majority of the patients in the aforementioned study received one or two ESWL treatments. The impact of repetitive ESWL on renal function has not been adequately addressed at this time.

There have been a few reports of patients developing renal failure after ESWL, and renal biopsies demonstrated the presence of complement fixation and antiglomerular basement membrane antibodies.[127,128] Westman and colleagues questioned whether ESWL played a role in the development of renal failure because they did not find an increased number of autoantibodies associated with glomerulonephritis in 59 consecutive patients who underwent ESWL.[129]

Although animal models have demonstrated that the smaller or underdeveloped kidney appears to be more susceptible to shock wave injury, a number of longitudinal studies performed on children who received ESWL demonstrated no reduction in renal function or growth over time.[130] One study, by Lifshitz et al., did report attenuated renal growth in children subjected to ESWL.[118] Given limited stone treatment options in children, ESWL is still an acceptable treatment in this group.

Shock wave lithotripsy in patients with preexisting renal insufficiency or a solitary kidney has also been studied. Chandhoke and colleagues found stable renal function after ESWL in patients with solitary kidneys or serum creatinine levels <3 mg/dL. Only patients with serum creatinine levels >4 mg/dL continued to have worsening renal function after ESWL, suggesting continued insult from the primary renal disease.[131]

There is no question that shock wave energy induces renal trauma, with acute histologic evidence of injury at biopsy 1 week post treatment[132] and reduced renal plasma flow immediately post treatment.[133] The renal papilla is

particularly susceptible to shock wave damage, with bleeding initiating inflammatory response and subsequent scarring.[134] Evidence of parenchymal scarring post ESWL was noted in both animal[135] and human studies.[136] Yet it appears that, in the majority of patients, this renal trauma has no significant long-term impact on the renal function.[109,137] Better designed longitudinal studies are needed to assess the impact of repetitive ESWL, especially in patients most susceptible to renal injury.

In the meantime, the judicious use of ESWL should help limit any reduction in renal function. This includes close monitoring for obstructive complications. Some have advocated the administration of free radical scavengers such as allopurinol, nifedipine, verapamil, and mannitol to limit acute renal injury.[138–141] The experience with pharmacologic protection is too limited to advocate its use at this time. Others have shown in animal and human studies that pretreatment with lower energy shock waves may reduce renal injury through vasoconstriction.[21,23]

Diabetes Risk

Theoretical risk of diabetes post ESWL is due to close anatomic position of the pancreas to the treated renal parenchyma, especially on the right side. As detailed above, pancreatic hematomas and histologic changes have been noted in pancreatic tissue post ESWL.[89] In porcine models, single ESWL was not shown to increase risk of diabetes after ESWL, despite specifically targeting renal parenchyma close to the pancreatic tail.[142,143] Similarly, human studies of 9 and 17 years' follow-up were reassuring, with no convincing evidence of elevated diabetes risk.[116,144]

Fertility Effects

Shock wave energy delivered to distal ureteral stones can theoretically injure gonadal tissue. Animal models have been used to determine the acute effects of delivering shock wave energy to the ovary. Recker and colleagues demonstrated minimal subcapsular bleeding, desquamation of superficial cells, and loss of microvilli immediately after shock wave energy was delivered to the rat ovary. However, these were transient and had resolved by 35 days.[145] McCullough and associates demonstrated normal reproductive ability in rats that had shock wave energy delivered to the ovaries. In addition, there were no teratogenic effects noted in the progeny.[146]

Studies of female patients have focused on the subjects' ability to reproduce after ESWL. Two studies evaluated women who underwent ESWL for distal ureteral stones and noted no fertility problems or genetic abnormalities in their children.[147,148] Despite this, the use of ESWL in girls or women of reproductive age harboring distal ureteral stones remains controversial, particularly due to the medicolegal implications of ESWL treatment in this cohort.

Male gonadal function also has been assessed in patients subjected to ESWL. Perisinakis and coworkers compared the radiation dose to gonadal tissue between ESWL of proximal and distal stones and found four times higher radiation exposure to the testes during ESWL for distal stones. They postulated that this would result in a four times higher genetic defect risk in the children of patients, although the overall risk still is thought to be exceedingly rare.[149] Worsening of semen parameters in men who underwent ESWL for distal ureteral stones has been noted. Fortunately, the effects were self-limited, and parameters returned to baseline within 3 months.[150,151] Reports of transient hematospermia in men who have been subjected to ESWL for distal ureteral stones are reflective of the potential temporary perturbation of the male reproductive tract.[152]

Finally, pregnancy remains an absolute contraindication to ESWL treatment, although there is at least one case report of successful treatment of proximal ureteral stone at 25 weeks' gestation.[153] In that particular case the patient was insistent on ESWL treatment despite extensive discussion of the risks.

Potential Long-term Complications

ESWL has been shown to produce acute renal injury, primarily vascular injury with parenchymal hemorrhage and subsequent inflammation, fibrosis, and loss of functional renal tissue.[136,154–156] As discussed above, as yet there is no evidence this trauma would translate into long-term renal dysfunction. There is, however, emerging evidence that repeated ESWL may increase subsequent stone formation risk,[157,158] particularly of calcium phosphate (CaP) composition.[159,160] For example, in porcine models, ESWL causes damage to medullary ascending limbs with a resultant rise in pH. This in turn can increase the risk of CaP stone formation.[161] CaP stones, brushite in particular, are notoriously difficult to treat, making it a concerning development.[162,163] Further studies in this area detailing pathogenesis and clinical implications are awaited.

Strategies to Reduce Risk of Complications

There are a number of methods to reduce complications of ESWL therapy. First, ESWL at 60 shock waves (SW)/min compared to 120 SW/min significantly reduced the size of the acute hemorrhagic lesions in a porcine study.[164] The slower rate at 60 SW/min has also been shown to improve human stone treatment outcomes in a meta-analysis.[165] Unfortunately, slowing the shock wave rate will increase the treatment time. Second, gradual ramping up of voltage (e.g., 100 shocks at low voltage) has also been shown to reduce the risk of hematoma formation in both porcine and human studies.[23,166] This is presumably due to the protective effect of renal vasoconstriction, as confirmed by the rise in the renal resistive index.[21,167,168] The effects of escalating the voltage on stone clearance are conflicting with improvement in one randomized trial but not in the other.[169,170] Third, the protective effect of voltage ramping is amplified by the (~3 min) pause following initial low voltage shocks, and this too should be included in routine treatment protocols.[171,172]

The current standard is treatment at low-to-moderate acoustic pressures with as few shock waves as possible, to minimize acute and lasting tissue injury, and at a slow shock wave rate (60 SW/min or slower), to enhance stone breakage and reduce tissue damage.[172] Next, effective coupling of the treatment head to the patient improves transmission of acoustic energy and reduces the required number of shock waves. For example, coupling defects of only 2% coverage reduced the breakage of model stones by as much as 20–40%.[173] An effective method is to apply the gel directly from the stock jug as a mound to the center of the treatment head, then press the cushion against the patient. The gel can be further spread out by increasing the water inflation pressure of the cushion.[172]

Since degree of renal injury is dose-dependent for pulse amplitude and shock wave number,[172] regular monitoring of stone fragmentation to avoid overtreatment is warranted.[174] Strategies to reduce patient movement and respiratory excursion (e.g., adequate anesthesia) allow for improved shock delivery to the target stone. Controlling blood pressure and avoiding anticoagulant use will reduce hematoma risks. Avoiding distal ureteral obstruction is also renoprotective.[175] Reserving ESWL for stones <2 cm in size will reduce risks of Steinstrasse and potential downstream obstruction.[176] With regard to antibiotic prophylaxis in patients with sterile preoperative urine, a meta-analysis did not show evidence for routine antibiotic administration to reduce risk of UTIs and sepsis in patients without stents, catheters, or infected stones.[49]

Finally, increased risk of long-term adverse effects is associated with multiple lithotripsies. Careful patient selection and consideration of alternative treatment approaches in treatment-resistant cases are recommended.

Conclusions

ESWL is generally a safe and effective treatment for patients with nephrolithiasis. Its noninvasive manner offers several advantages; however, as with any therapy, complications may result. Complications can be limited with proper patient selection, good preparation, and correct technique.

References

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Chapter 29 Questions

1. What is the reported incidence of renal hematoma post extracorporeal shock wave lithotripsy (ESWL)?
   a. <1%
   b. 1–5%
   c. 5–10%
   d. 10–15%
   e. >15%

2. Steinstrasse management options include:
   a. Ureteroscopy
   b. Percutaneous nephrostomy insertion
   c. Conservative management
   d. Ureteral stent insertion
   e. All of the above

3. With regard to injuries to other organs, which of the following is NOT true?
   a. Mild degree of hepatic injury with raised liver enzymes is common
   b. Children are more susceptible to lung injury with ESWL
   c. Pancreatitis is commonly seen following ESWL
   d. Gastric or duodenal erosions are seen in up to 80% of patients after ESWL
   e. Subcapsular hepatic hematoma is typically managed conservatively

4. All of the following are recommended to reduce the risk of ESWL complications EXCEPT:
   a. Reducing shock wave rate
   b. Gradual voltage escalation (power ramping)
   c. Adding a 3-min pause following initial low-voltage shocks
   d. Prophylactic antibiotic administration to all patients presenting for ESWL
   e. Applying gel directly from the stock jug to the center of the treatment head to improve coupling

5. Cardiac arrhythmias associated with ESWL:
   a. Are typically associated with gated ESWL
   b. Resolve with cessation of ESWL
   c. Often require cardioversion
   d. Are more frequent in the pediatric population
   e. Occur in <5% of patients

6. Regarding risks of ESWL, which of the following is NOT true?
   a. Increased risk of hypertension is noted in younger patients
   b. Patients with renal calculi are at a higher risk of developing hypertension than the general population
   c. Worsening of semen parameters is typically transient
   d. Repeat ESWL increases subsequent stone formation risk
   e. ESWL causes acute renal injury with inflammatory response and subsequent scarring

7. Acute effects of ESWL include:
   a. Predominantly cortical injury
   b. Increase in renal plasma flow
   c. Urothelial sloughing
   d. Rupture of interstitial capillaries
   e. B and D

8. Regarding sepsis post ESWL, which of the following is NOT true?
   a. Occurs in <2% of patients
   b. Warrants broad-spectrum antibiotic prophylaxis in struvite stones
   c. Associated with elevated CRP
   d. Higher risk in patients with oxalate-containing stones
   e. Increased in patients with preexisting UTI, indwelling stent, or nephrostomy tube

9. Renal hematomas post ESWL:
   a. Are usually managed conservatively
   b. Do not typically cause hypertension
   c. Can take up to 5 years to resolve completely
   d. Are reduced by medically managing hypertension
   e. All of the above

10. Regarding anticoagulant use with ESWL:
    a. Aspirin should be stopped 3 days prior
    b. The need for anticoagulants is a relative contraindication for ESWL
    c. Aspirin can be safely continued throughout treatment
    d. Few guidelines exist
    e. B and D

Case Studies

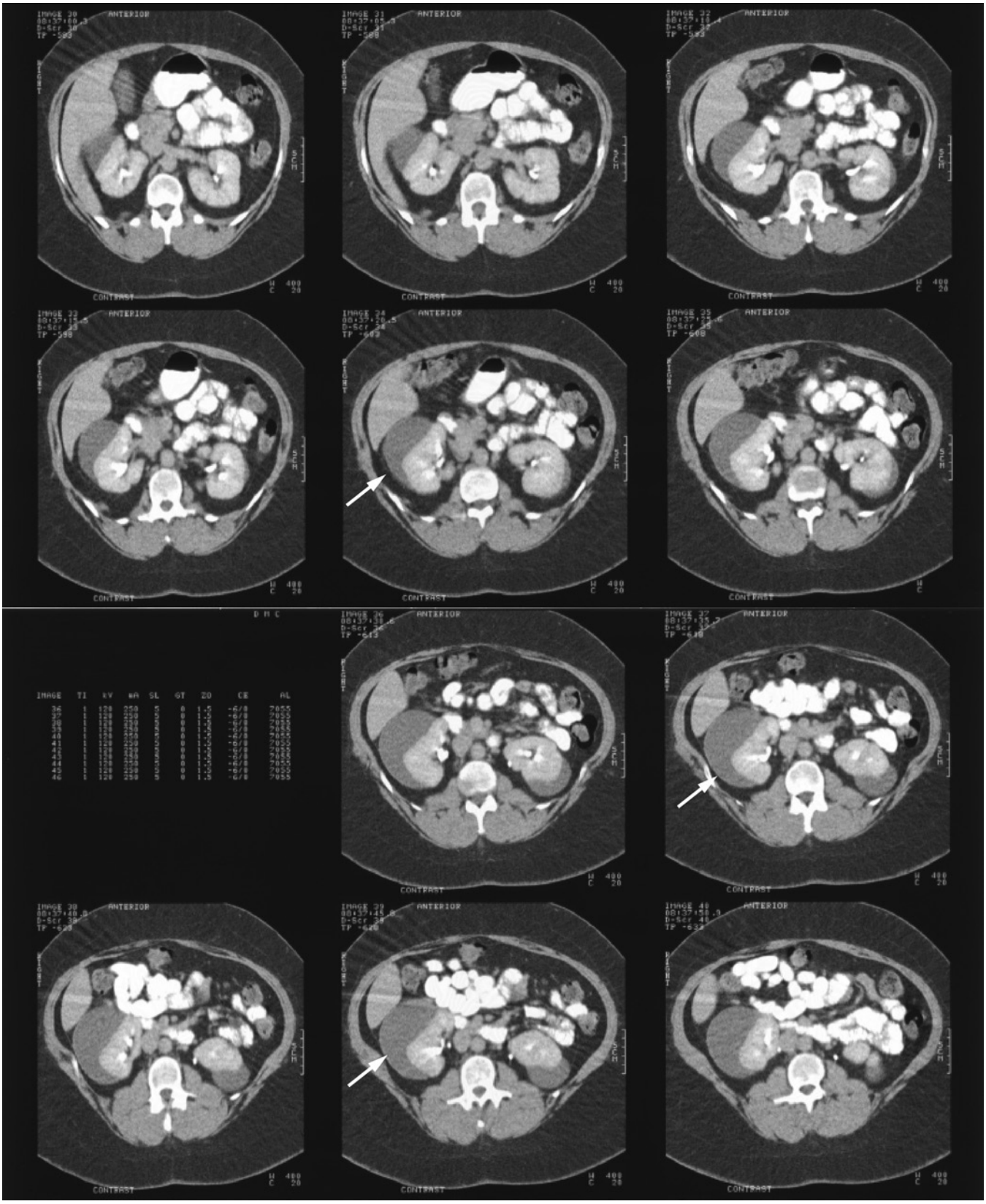
CASE 1

A 34-year-old female patient underwent right ESWL and was discharged home the same day. Routine follow-up imaging was obtained in clinic 6 weeks after the procedure (Case Fig. 29.1). The patient is asymptomatic.

1. What is the management of delayed presentation of large perirenal hematoma?
   a. Percutaneous drainage by interventional radiology
   b. Laparoscopic decortication
   c. Thrombolysis
   d. Observation
   e. Open surgical drainage to ensure complete resolution

2. What is the typical outcome of perirenal hematoma?
   a. Mild but persistent hypertension
   b. Gradual resolution
   c. Abscess formation
   d. Ongoing hematuria
   e. Chronic pain

3. Risk factors for post-ESWL perirenal hematoma include:
   a. Poorly controlled hypertension
   b. Advanced age
   c. Urinary obstruction
   d. Corticosteroid therapy
   e. All of the above



Case Figure 29.1

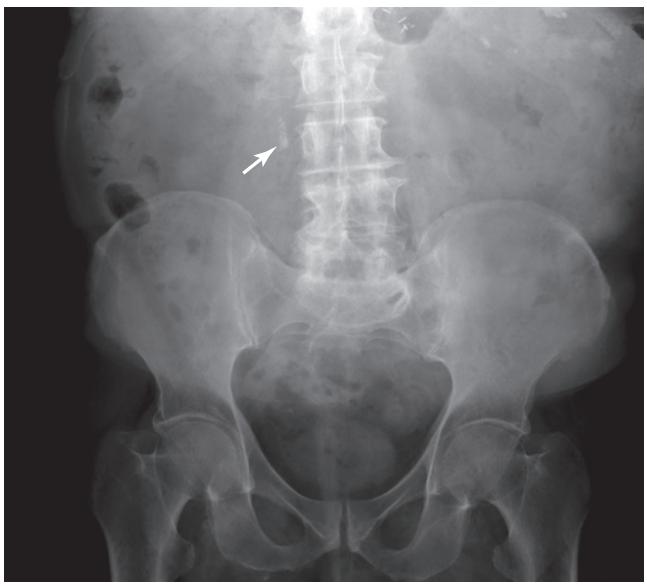
CASE 2

A 53-year-old male patient presents with pain and fever 38.3°C (100.9°F) 2 days following right ESWL for a 12-mm mid-pole calculus. A KUB x-ray is performed (Case Fig. 29.2). The patient is normotensive.

1. Acute management of this patient includes:
   a. Percutaneous nephrostomy drainage or ureteral stenting
   b. Ureteroscopy and stone fragment treatment/extraction
   c. Urine culture, initiate broad-spectrum antibiotics and observe
   d. Repeat ESWL
   e. Percutaneous nephrolithotomy

2. Once acute symptoms are treated definitive management of this patient might include:
   a. Ureteroscopy and stone fragment retrieval
   b. Repeat ESWL
   c. Observation with serial imaging
   d. Addition of alpha blockers
   e. All of the above

3. Reported incidence of Steinstrasse post ESWL is:
   a. <2%
   b. 2–10%
   c. 10–18%
   d. 18–25%
   e. >25%



Case Figure 29.2

Answers

1. **b.** Studies report low incidence of post-ESWL renal hematoma at 1–5%.[13]
2. **e.** As discussed in the chapter, Steinstrasse can be managed in a number of ways, depending on patient and stone factors.
3. **c.** Pancreatitis is rarely reported post ESWL.[88]
4. **d.** Routine antibiotic administration is not necessary for uncomplicated patients with sterile urine prior to ESWL.[49]
5. **b.** Arrhythmia is precipitated by ESWL shocks in some patients, thereby resolving with cessation of shocks.
6. **a.** Risk of hypertension is higher in older patients.
7. **d.** Tissue effects of ESWL are discussed in this chapter under the "RENAL INSUFFICIENCY" heading.
8. **d.** Struvite stones present the highest risk of sepsis.
9. **e.** Renal hematomas post ESWL are discussed at the beginning of this chapter.
10. **e.** Complexities of managing anticoagulants in ESWL are discussed in this chapter. Aspirin should be stopped 7 days prior to ensure complete reversal of anticoagulant effects.

CASE 1

1. **d.** Since most hematomas resolve over time, observation is an appropriate option in an asymptomatic patient.
2. **b.** Most hematomas resolve spontaneously.
3. **e.** All of these are known risk factors for hematoma formation.

CASE 2

1. **a.** Given concern for sepsis in combination with obstruction (steinstrasse), the first management step is decompression of renal collecting system with either a nephrostomy or a ureteral stent.
2. **e.** All listed options may be appropriate depending on the severity of symptoms, stone size and surgical factors.
3. **b.** The reported incidence of steinstrasse 2–10%[28–31].

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SECTION VI

Complications of Laparoscopic/Robotic Procedures

30 Special Considerations in Laparoscopy

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CHAPTER OUTLINE

Introduction
Patient Selection and Anesthetic Considerations
Positioning
Access Injuries
Minor Vascular Injuries
Major Vascular Injuries
Superior Mesenteric Artery Injury
Electrosurgery
Mechanical Failure
Visceral Injuries
Pleural/Diaphragmatic Injury
Conclusions
Chapter 30 Questions and Answers

KEY POINTS

1. Laparoscopy is associated with excellent outcomes and low complication rates in properly selected patients.
2. Careful patient positioning and knowledge of specific neuromuscular injuries are critical to prevention, recognition, and management of neuromuscular injuries.
3. The laparoscopic surgeon must be facile with laparoscopic access, quickly recognize and manage associated complications, and be equipped to convert to an open approach when necessary.
4. The laparoscopic surgeon should understand the instruments, tools, and electrosurgical technology used. The laparoscopic surgeon should be aware of hazards of direct injury, insulation failure, and capacitive coupling.
5. Always consider the potential for injury to the superior mesenteric artery during left-sided nephrectomy, and the inferior vena cava during dissection of the right gonadal vein, particularly when the anatomy is distorted by tumor, lymph nodes, or prior surgery.
6. Bowel injuries require prompt diagnosis and management.

Introduction

Since the performance of the first laparoscopic nephrectomy in 1991, the expansion of surgical technology has enabled application of laparoscopic techniques to nearly every operation in urology.[1] In fact, laparoscopic approaches have become the standard of care for many of these operations with advocates citing decreased patient pain, shorter hospitalizations, lower intraoperative blood loss, and, in some cases, decreased technical difficulty. When laparoscopy was initially introduced complications were often attributed to novel technical difficulties and surgeon inexperience. However, large contemporary series of urologic laparoscopic surgery report overall intraoperative and postoperative complication rates of 4.7% and of 17.5%, respectively, which are similar to historical series, thus suggesting that not all complications can be circumvented via technologic advancement and experience.[2]

Although laparoscopic techniques are often analogous to open surgery, there are many salient differences in patient selection, instruments, and technique as well as complications unique to laparoscopy. It is incumbent upon the urologic laparoscopist to be aware of these factors in order to prevent complications when possible and to promptly recognize and expertly manage them when they do arise. In this chapter we aim to outline many of the special considerations and unique complications of urologic laparoscopy with a focus on diagnosis and management.

Patient Selection and Anesthetic Considerations

Appropriate selection of patients for surgery is critical to ensure a good outcome and is especially important when determining optimal surgical approach. Historically there were considered to be several absolute contraindications to laparoscopic surgery; however, laparoscopy may now be safely undertaken in almost any patient. Despite the expanding role of laparoscopy and its relative safety, certain patient factors, including uncontrolled bleeding diathesis,

active bowel perforation or obstruction, extensive past surgical history, or a history of diffuse peritonitis, are associated with greater risk of complication and should give the surgeon great pause before pursuing a laparoscopic approach.

Obesity is becoming increasingly more common in the Western world. While obesity was historically considered an absolute contraindication to laparoscopic surgery, contemporary series suggest that while obese patients may be at higher risk of overall complications this risk is not increased by use of a laparoscopic surgical approach.[3,4] Proper positioning of the obese patient can be challenging, but is also critical for prevention of deep vein thrombosis, neuropraxia, and rhabdomyolysis for which obese patients are at higher risk irrespective of surgical approach.[5] Often special operative tables and equipment are necessary, and the surgeon must be aware of weight limitations of commonly used equipment. When placed in the steep reverse Trendelenburg position, obese patients have increased pressure on the diaphragm resulting in decreased respiratory compliance and subsequent difficulty with mechanical ventilation.[6] If the anesthesia team is having difficulty ventilating a patient, it is often necessary to decrease the pneumoperitoneum pressure, although this may increase the technical difficulty of the operation. In contrast to the Trendelenburg position, obese patients tolerate the flank position well, both from a hemodynamic and a respiratory standpoint.[5] Please see Chapter 9 for more information.

Patients with cardiopulmonary disease are at unique risk during laparoscopy using carbon dioxide insufflation. Carbon dioxide is highly soluble and readily diffuses into extra-pulmonary tissues and fluids, which may lead to hypercarbia even many hours postoperatively. Patients with chronic obstructive pulmonary disease (COPD) may be unable to increase their ventilation to respond to hypercarbia and should be closely monitored with serial ABGs postoperatively. COPD is not an absolute contraindication to laparoscopy, but in the setting of severe COPD and/or anticipated long operative time an open surgical approach should be considered.[7] Helium is a physiologically inert and noncombustible gas that does not contribute to hypercarbia and can be used as an alternative insufflant. Although helium is significantly more expensive than carbon dioxide, it can be used to salvage a case complicated by severe hypercarbia that may otherwise be aborted or converted to an open approach.[8]

While surgical indications should be carefully considered in pregnant patients, pregnancy itself is not an absolute contraindication to laparoscopy. Performing laparoscopy on pregnant patients presents several unique considerations with regard to obtaining initial access, port placement, and prolonged pneumoperitoneum. Initial access should be away from the gravid uterus and is generally obtained at Palmer's point located in the left upper quadrant in the subcostal midclavicular line. Port placement is generally more cephalad and should be performed under direct vision in order to minimize the risk of uterine injury. Pneumoperitoneum pressure should be set at 10 mm Hg and should not be increased above 15 mm Hg as venous return is already compromised by a gravid uterus. Prolonged pneumoperitoneum should be avoided as hypercarbia could have harmful effects on the fetus. [9,10]

POSITIONING

Careful attention to appropriate patient positioning is critical to minimize the risks of nerve injury and rhabdomyolysis during and following laparoscopic surgery. In a review of 4000 insurance claims, complications related to nerve injuries accounted for 16% of claims associated with laparoscopic surgery. Of these, ulnar nerve injuries were most frequent (28%) followed by brachial plexus injuries (20%).[11] Mechanisms of nerve injury related to positioning include stretching, compression, and ischemia. Ulnar nerve injuries are often related to external compression of the nerve as it courses behind the medial epicondyle in the antecubital tunnel where it is not shielded by muscle or bone. Injury to the ulnar nerve results in hypoesthesia of the medial half of the fourth finger and the entire fifth finger. Weakness can lead to difficulty with thumb adduction. Claw hand may be seen due to hyperextension of the fourth and fifth digits at the metacarpophalangeal joints, and flexion at the interphalangeal joints.[12] Careful attention to avoid compression injury through adequate padding of the elbow is necessary, especially with the use of gutter armrests. The brachial plexus is at highest risk of stretch injury when the arm is abducted and extended, especially in deep Trendelenburg and with use of shoulder braces.[11] Signs of brachial plexus injuries vary widely but most commonly include sensory deficit to the shoulder area and impairment of upper arm abduction.

A large majority of lower-extremity positioning complications are related to compression of the peroneal (fibular) nerve as it passes laterally to the head of the fibula.[13] Peroneal injuries manifest as paresthesia over the lateral foot and inability to dorsiflex the foot (foot drop). Sciatic nerve injuries are less common and are caused by excessive hip flexion in lithotomy. This injury is exacerbated when the knees are minimally flexed as this increases stretch on the sciatic nerve. Sciatic nerve injuries present as paresthesia over the posterior legs and feet and weakness in foot extension and flexion. To avoid these lower-extremity injuries patients in lithotomy must be carefully positioned to ensure the weight of the leg is supported in the heel, external rotation and hip flexion are not excessive, and the lateral aspect of the leg is appropriately padded (Table 30.1).

Rhabdomyolysis following laparoscopic surgery is a severe and potentially life-threatening complication with a reported incidence ranging from 4.9% following laparoscopic renal surgery to 0.13% in a series of over half a million patients following urologic surgery.[14,15] In the surgical setting, rhabdomyolysis most commonly occurs secondary to prolonged direct pressure on soft tissues resulting in structural changes and necrosis of skeletal muscle. Once the pressure is released, ischemia-reperfusion injury can occur and the intracellular components of lysed cells are released into the systemic circulation. This leads to myoglobinuria, which has a direct toxic effect on renal tubules and can cause devastating acute renal failure, particularly when occurring in the context of extirpative renal surgery. The clinical signs of rhabdomyolysis are myglobinuria, muscle weakness, pain, and acute renal failure. The creatinine kinase (CK) is elevated and is usually between 1000 and 100,000 IU/L.

Gelpi-Hammerschmidt et al. attempted to quantify the risk of postoperative rhabdomyolysis, reporting a 1.8%

Table 30.1 Common Positioning Nerve Injuries

Nerve	Location	Mechanism of Injury	Deficit
Ulnar nerve	Unprotected near medial elbow	External pressure on medial elbow, especially with arm gutters	Paresthesia of 4th and 5th finger, claw hand
Brachial plexus	Axilla	Hyperextension or abduction of arm, deep Trendelenburg, use of shoulder braces	Variable, paresthesias and weakness of upper extremity
Sciatic nerve	Well protected in thigh	Excessive hip flexion especially with extended knees	Paresthesia and weakness posterior leg, foot
Peroneal nerve	Lateral leg	External compression as it passes head of fibula, external hip rotation	Paresthesia over lateral foot and foot drop



Figure 30.1 Major Abdominal Vessels. The location of the major abdominal vessels and of the inferior epigastric vessels in relation to surface landmarks is shown in a photograph of a patient with the superimposed course of vessels. The umbilicus (arrowhead) acts as a superficial landmark for the aortic and vena caval bifurcation. Direct entry at 0 to 30 degrees in the sagittal plane by a needle or trocar creates a high risk of puncturing the aorta, right common iliac artery, or the left common iliac vein. The inferior epigastric vessels take an ascending course medially and eventually travel in the substance of the rectus muscle. A port placed at or just below the umbilicus at the paramedian location (arrows), such as is frequently done during pelvic cases (e.g., laparoscopic prostatectomy), poses a higher risk of causing injury to these vessels. (Copyright S. F. Matin, 2007.)

Box 30.1 Risk Factors for the Development of Rhabdomyolysis

- Robotic surgery (independent risk factor)
- Operative time greater than 5 hours
- Obesity
- Diabetes mellitus
- Male gender
- Poor padding
- Prolonged use of the kidney rest

incidence in patients with any three of the following five risk factors: operative time greater than 5 hours, robotic surgery, obesity, male gender, and Charlson comorbidity index greater than 2.[15] Other identified risk factors include preexisting renal disease, high intraoperative blood loss, and positioning factors such as poor padding of bony prominences, operative table flexion, and use of the kidney rest. A recent review also suggests that robotic surgery presents a greater risk for rhabdomyolysis compared to laparoscopic or open renal surgery likely due to comparatively longer operative times.[16] Rhabdomyolysis is often a devastating complication causing major collateral morbidity as well as increased resource utilization.[15] As such, once a clinical suspicion of rhabdomyolysis is established, aggressive treatment focused on vigorous hydration, urinary alkalization, and renal replacement therapy should not be delayed. While a less common complication of rhabdomyolysis, compartment syndrome is life threatening and requires decompressive fasciotomy for definitive management. In cases involving lithotomy for greater than 5 hours, sequential compression devices may increase the risk of compartment syndrome and should be used with caution[17] (Box 30.1).

ACCESS INJURIES

Obtaining initial peritoneal access is often the most dangerous step in laparoscopy, and multiple initial entry techniques have been described, each with the goal of minimizing morbidity (Fig. 30.1). These techniques can be broadly

Box 30.2 Tips for Safe Veress Placement

- Check the needle and ensure spring-loaded blunt tip is working
- Incise the skin prior to Veress placement
- Once placed, aspirate to observe for blood or succus
- Perform the saline drop test prior to insufflation
- Observe the insufflation pressures and stop and replace Veress if initial pressure reaches 6 mm Hg
- Percuss insufflating abdomen for asymmetric tympani
- If concerned about Veress placement, leave Veress in place, obtain another access, and observe Veress location with laparoscope

classified into "open" methods in which trocars are placed into the peritoneal cavity under direct vision, and "closed" methods in which instruments are passed blindly through the abdominal wall prior to insufflation. Of these, the most commonly used are the "open" Hasson and the "closed" Veress methods. However, other techniques including direct trocar entry, radially expanding trocars, primary insufflation through a hand assist port, and optical trocars may be used. No method of primary laparoscopic entry is absolutely safe, and experts disagree on which method provides the safest, most expedient, and most reliable means of obtaining laparoscopic access. This controversy is compounded by a lack of high-quality clinical data.

The surgeon should be comfortable with multiple methods of laparoscopic access. Because the Veress needle is inserted blindly, it should be used carefully (Box 30.2). The needle should be checked to make sure the spring-loaded blunt center is functioning. Once placed, multiple maneuvers may be employed to confirm intraperitoneal

position of the Veress needle. First, the needle should be aspirated to make sure there is no blood or succus indicative of vascular or visceral injury. Second, as a saline-filled syrine is disconnected from the Veress needle hub, the saline remaining in the needle hub should quickly drop into the abdomen in the so-called "drop test." If the fluid does not freely flow into the abdomen this may indicate that the needle is either not intraperitoneal or is abutting a structure that is limiting flow. During initial insufflation intraperitoneal pressures should not exceed 6 mm Hg, and higher pressures and/or a rapid rise in measured pressure may indicate extraperitoneal position. The abdomen may also be percussed during insufflation; asymmetric tympani could represent pre-peritoneal or colonic insufflation. If any of these steps raises concern for a visceral injury, the Veress needle should be left in place and alternate access should be obtained. Once access is obtained, the original Veress site should be inspected for any signs of injury. Veress needle injuries to bowel and bladder can usually be managed conservatively while trocar injuries invariably require operative repair.

An optical port may be utilized to place the initial trocar using a 0-degree laparoscope under direct vision either with or without initial insufflation. The layers of the abdominal wall (subcutaneous fat, anterior fascia, rectus, posterior rectus sheath, transversalis, and peritoneum) should be visualized during advancement to confirm intraperitoneal position. The tip of the optical trocar is usually radially dilating so rotation is important to traverse the layers of the abdominal wall. If this technique is employed prior to insufflation the initial access site should be located off midline so the layers of the abdominal wall can be visualized. The remaining ports should be placed under direct vision, and any adhesions seen near the desired port location should be taken down prior to trocar insertion.[18]

Open access is considered very safe as the surgeon retains direct visualization; however, it can be more technically challenging and complicated by pneumoperitoneum leakage (Box 30.3).[18] The technique is similar to a mini-laparotomy where a small incision is made near the umbilicus and taken down to fascia. The fascia is incised, the peritoneal cavity opened, and the trocar placed using a blunt obturator. Once in an intraperitoneal position fascial sutures are placed to secure the Hasson trocar and the balloon is inflated to create a seal between the trocar and the peritoneal edges enabling establishment of pneumoperitoneum.[19]

The Cochrane Collaboration released in 2015 a systematic review of all available prospective randomized controlled trials (RCTs) comparing laparoscopic entry techniques. In a review of three RCTs including 795 patients comparing open versus closed primary entry techniques, no differences were found with respect to incidence of visceral or vascular injury.[20–22] In the same series, the risk of failed entry, extraperitoneal insufflation, and omental injury were all less likely with use of open entry techniques, although the authors note that all reviewed studies were of low or very low quality.[20–24] Visualized trocar entry without insufflation ("direct trocar entry") is becoming increasingly popular as initial studies support its superior safety and speed. The Cochrane report included systematic review of five RCTs that reported lower risk of vascular injury with direct trocar entry, but no difference with respect to visceral injury.[20,25–28] See table 30.3 for a summary of randomized controlled trials comparing methods of initial laparoscopic access.

Another area of controversy is the necessity of laparoscopic trocar site closure in order to prevent hernia formation. The absolute incidence of trocar site hernia is unknown, but is estimated to be between 0.65% and 2.80% by large general surgery series and is likely underreported.[29] Although uncommon, such hernias may result in small bowel obstruction or incarceration and as such represent a serious source of morbidity and mortality in laparoscopic surgery. Initial studies of bladed trocars supported the necessity of trocar site fascial closure as hernia rates at 12-mm trocar sites fell from 8.0% to 0.22% with formal closure.[29–32] Since the development of bladeless and radially dilating trocars that permit atraumatic separation of the abdominal wall, the necessity of fascial closure is less clear. A randomized prospective trial comparing bladed to bladeless trocars concluded that routine closure in the absence of risk factors was not necessary.[33] Another study of 747 patients undergoing laparoscopic Roux-en-Y bypass with the use of radially dilating trocars reported no hernias at extraumbilical sites that were not closed; however, there was a 1.2% rate of hernia at the umbilical site of Hasson entry despite formal fascial closure.[34] The authors similarly concluded that routine closure of extraumbilical trocar sites was unnecessary.

It is imperative to maintain a high index of suspicion for trocar site hernias as clinical signs and physical exam findings can be deceiving. This was demonstrated in a recent retrospective review of 1055 patients undergoing either RALP or laparoscopic renal surgery at a single center.[35] The authors describe seven hernias (0.66%), all of which occurred at 12-mm trocar sites where fascia was not closed. Six of the seven patients with hernia presented with signs and symptoms of bowel obstruction, and all required operative intervention. Although diagnosis of hernia was made on cross-sectional imaging, four of the seven patients were noted to have intra-fascial hernias (occurring between the transversalis and internal oblique fascia) at the time of surgery and were without overt evidence of hernia on physical exam.

Currently it is our practice to close all 12-mm port sites and remove all trocars under direct vision to minimize the risk of hernia.

Minor Vascular Injuries

Vascular injury is the most common intraoperative complication of urologic laparoscopy, ranging from 2.6% to 19.8% in large series.[2,36,37] The majority of these injuries occur while obtaining laparoscopic access or during dissection. Types of vascular injury include injury to the abdominal wall vasculature, great vessel injury, or mesenteric artery injury.

The inferior epigastric vessels are the most common site of minor vascular injury, occurring in 2.5% of laparoscopic hernia repairs.[38] Although injury to the vasculature of the abdominal wall is less likely to be life threatening, it may confer considerable morbidity requiring conversion to an open approach, transfusion, and the need for additional procedures or operations. The anatomic location of the inferior epigastric vessels at the lateral aspect of the rectus sheath place them at risk for injury that invariably occurs during placement of secondary cannulas. Significant injury

is most common in the lower abdomen, as the epigastric vessels exist as a plexus in the upper abdomen rather than a discrete vessel vulnerable to laceration.[39]

Injury to the abdominal wall vasculature is most commonly identified at the time of initial port placement, but can also be recognized when ports are removed, or present in a delayed fashion as abdominal wall or rectus sheath hematomas. Techniques to avoid abdominal wall vascular injury include use of the smallest appropriate cannula, transillumination of the body wall to identify and avoid large vessels, an adequate skin incision to avoid use of excessive force, not angling trocars toward the midline, and placement of cannulas under direct laparoscopic vision.[39] Particularly in obese patients use of a "finder" needle with local anesthetic can be useful in planning port placement and avoiding minor vascular injury. This additionally allows infiltration of local anesthetic, which can aid postoperative pain control.

Once an injury to the inferior epigastric vasculature is identified, there are multiple techniques available to obtain hemostasis. Initially, direct pressure can be applied by angling the laparoscopic cannula to tamponade the bleeding vessel. The vessels can be suture ligated either by extending the port site skin incision to gain adequate exposure for direct suturing or by use of a laparoscopic-assisted, transabdominal suture technique with either a Carter-Thommason device or Keith needle. In either case, placement of either interrupted or horizontal mattress sutures or a wide-based figure-of-eight suture is usually necessary to control hemorrhage. As a last ditch maneuver, a Foley catheter can be placed through the abdominal wall fascia, the balloon inflated intraabdominally, and pulled snug against the abdominal wall to provide tamponade for 24–48 hours or until hemostasis is achieved.

Abdominal wall vascular injury can also result in rectus sheath hematoma, which most commonly presents in a delayed fashion with palpable abdominal mass and severe abdominal pain.[40] While all patients are at risk for developing a rectus sheath hematoma, those on anticoagulation are at higher risk. Computed tomography is the imaging study of choice in diagnosis of rectus sheath hematoma.[40] The majority of rectus sheath hematomas are self-limiting, resolving with careful observation and reversal of anticoagulation if applicable; however, hemorrhagic shock occurs in 37.5% of cases with mortality as high as 25% in anticoagulated patients.[41] In severe cases selective angioembolization is preferred to surgical exploration, as the latter will release any tamponade, is less likely to be definitive as localization of the injury may be challenging or impossible, and carries considerable morbidity.

Box 30.3 Tips for Successful Trocar Placement[79,80]

Factors Facilitating Safe Placement of Trocars During Laparoscopic Surgery

- Low table height
- Noting of anatomic landmarks and abdominal scars
- Adequate skin incision size for trocar
- Application of appropriate axial force during trocar insertion
- Use of the Trendelenburg position (for umbilical access)
- Elevation or stabilization of abdominal wall
- Transillumination of abdominal wall vessels
- Avoidance of lateral deviation of needle or trocar
- Avoidance of angling of needle or trocar toward the midline

Major Vascular Injuries

Major vascular injuries are rare during laparoscopy, but are the most common cause of intraoperative death at up to 15%, second only to anesthetic complications.[39,42] While the specific incidence of these injuries is lacking in the urologic literature, it ranges from 0.03% to 0.30% in large series in the general and gynecologic surgical literature.[39] Most vascular injuries occur during initial establishment of pneumoperitoneum with a Veress needle (39.8%), but can also occur with placement of the primary trocar (37.9%) or with secondary trocars (22%).[43] Of interest, a large French series found that while the rate of overall complications decreased with increasing surgeon experience, the rate of vascular injury remained static at 0.02% independent of surgeon experience.[44]

The anatomy of the retroperitoneal vasculature places the distal aorta and common iliac vessels at highest risk of injury during periumbilical laparoscopic access (see Fig. 30.1), as these vessels can be as close as 2 cm from the anterior abdominal wall in thin patients. Arterial injuries are most common, and when venous injuries do occur they are usually in conjunction with arterial injury.[45] A review of vascular injury during gynecologic laparoscopy reported that distal aortic injury was most common (25%), followed closely by injury to the right common iliac artery (21%), with the remainder of arterial injuries being distributed between the bilateral external and internal iliac arteries (29%).[45–47] Injury to the inferior vena cava (IVC) occurred in 11% of patients.[45–47] The IVC is at particular risk during dissection of the gonadal vein during right-sided nephrectomy. As such, it is critical to release the gonadal vein away from the ureter and allow it to return medially in order to avoid avulsing the gonadal vein from the IVC.[48]

Major vascular injuries occurring during the access phase of laparoscopy are most commonly signified by identification of a large retroperitoneal hematoma. Depending on the location and nature of the injury, blood within the peritoneal cavity may be scant or absent.[39] Additional signs of injury include hypotension and hemorrhagic shock, as well as decreased end-tidal carbon dioxide as a result of carbon dioxide embolism. Lastly, if there is significant intraperitoneal bleeding, absorption of visible light by hemoglobin may result in poor laparoscopic visibility serving as another clue as to possible vascular injury.[39]

While the principles of managing significant intraoperative hemorrhage during laparoscopy are the same as during open surgery, the specific techniques differ. If the site of vascular injury is immediately apparent, laparoscopic grasping and dissecting instruments can be used to apply direct pressure and obtain initial control. Care should be taken not to injure adjacent structures or worsen the vascular injury through careless maneuvers or inappropriate use of instruments. Once temporary control is obtained, the anesthesia team can be notified to allow for appropriate resuscitation and to ensure availability of blood products. The insufflation pressure can be increased to 20 mm Hg in order to help tamponade bleeding; however, this maneuver

carries the risk of causing venous gas embolism should there be a significant venous injury. If bleeding is sufficiently controlled and visibility maintained, it is reasonable to continue laparoscopic dissection to further expose the site of injury. Once definitively identified, the source of bleeding can be controlled with electrocautery, surgical clips or staplers, suture ligation, or hemostatic agents. Additional ports, including hand-assist ports, may be placed in order to improve exposure and facilitate passage of instruments.

If bleeding cannot be controlled using laparoscopic methods, or if an injury is identified that will require formal vascular repair, conversion to an open surgical approach may be necessary. It is important that this decision be made quickly because even experienced surgical teams can take a considerable amount of time to convert and significant blood loss can occur in the interim. Open surgical instruments should be at hand during all laparoscopic cases, and it is prudent to plan the open incision site at the beginning of difficult cases where conversion is more likely. If laparoscopic or robotic instruments are being used to provide direct pressure, these instruments should remain in place and pneumoperitoneum maintained during conversion to aid hemostasis and tamponade. The open incision should be planned in order to gain optimal exposure for vascular repair; however, extension of an existing port site is preferable as laparoscopic instruments, or the laparoscope itself, can be used to expose and facilitate division of the abdominal wall.

Superior Mesenteric Artery Injury

A special consideration during laparoscopic renal surgery is the possibility of injury to visceral vasculature, particularly the superior mesenteric (SMA) and celiac axis (CA). Anatomic studies by Brunet et al. demonstrated that the average proximity of the ostia of the left renal and superior mesenteric arteries, and the ostia of the CA and SMA, are 11.3 mm and 3.8 mm, respectively.[49] This close anatomic proximity places these vascular structures at high risk of injury during laparoscopic renal surgery, especially in the setting of large renal or adrenal masses, adenopathy, adherence of the kidney to surrounding tissues, and accessory renal vessels that may distort normal anatomy. Anomalies of the renal vasculature are frequent, with Kaneko et al. noting 21.1% of renal arteries with multiple origins, while aberrations of the aorta and mesenteric vasculature are extremely rare.[50,51] Therefore it is imperative to review preoperative imaging to identify all renal arterial branches and to exercise extreme caution prior to vascular ligation when operative findings do not correlate with preoperative imaging. In difficult laparoscopic dissections, the gonadal vein can be used as a guide to definitively identify the hilar vessels. While difficult hilar dissection and failure to progress are commonly cited reasons to convert from a laparoscopic to open surgical approach, only 7% of reported SMA injuries during left nephrectomy occurred during laparoscopy, suggesting that open surgical exposure does not completely protect from these injuries.[52–55]

Injury to the SMA may be detected intraoperatively by identification of hemorrhage, signs of hemorrhagic shock, worsening metabolic acidosis due to bowel ischemia, and oliguria due to shock and massive fluid shifts to the bowel. Notable clinical signs of bowel ischemia such as serosal color change, loss of palpable arterial pulses, and lack of intestinal peristalsis may occur late or not at all depending on the level at which the SMA was ligated.[56] Postoperatively significant mesenteric arterial injury classically presents with severe epigastric abdominal pain as well as the above listed signs; however, pain may be masked in the postoperative setting. As unrecognized SMA injuries generally result in acute intestinal ischemia and death in most patients, a high index of suspicion for vascular injury is critical especially for left-sided renal surgery, and prompt vascular surgical consultation should be obtained if there is any question of mesenteric vascular injury.

Electrosurgery

Urology has always been on the leading edge of medical technology. Understanding how surgical technology works is critical to operating safely and addressing issues when they arise. Electrosurgery is the single most used piece of surgical technology, but is often poorly understood and is also one of the most common causes of litigation.[57] While often used incorrectly, the term "electrocautery" actually refers to a direct current heating a probe that in turn burns tissue (e.g., portable ocular cautery stick) and is used very rarely in modern surgical technique. Electrosurgery or diathermy refers to the application of a current to the tissue itself and is most commonly used in the operating room.

Monopolar is the most commonly utilized electrosurgical modality. This technology passes an alternating current through a circuit coursing from the generator, to the electrode (pencil or instrument), through the patient, and then back to the generator via the return electrode ("grounding pad"). Central to the utility of monopolar electrosurgery is the concept of current density. The monopolar current density is highest at the point of contact between the electrode and the patient's tissue and rapidly decreases further from the electrode. As the rate of tissue heating is proportional to the square of the current density, only this tissue near the tip of the electrode is heated. Therefore the smaller the surface contact of the electrode to the tissue, the greater the current density and the more quickly that tissue is heated and desiccated. Conversely, the larger the surface contact between the electrode tip and the tissue, the more slowly the tissue is heated and dissected.

Monopolar electrosurgical injuries result from the unintentional application of current to tissue due to unintentional direct contact, direct coupling, poor return electrode application, insulation failure, or capacitive coupling. Unintentional direct contact is self-explanatory and usually occurs when the electrode is activated when the instrument is not in view. Direct coupling occurs when the electrode is in contact with a metal instrument that is in turn contacting tissue. An example of intentional direct coupling is the application of monopolar current to a pair of forceps grasping a bleeding vessel. In this case, the area of tissue contact is small, the current density is high, and the energy applied to the tissue is also high resulting in coagulation of the vessel. Conversely, if the forceps accidentally contacts a surface outside the immediate operative field such as the abdominal wall in addition to the vessel, the current density is low and the energy imparted to intended tissue will also be low (noted as "grounding out"). Lastly, direct coupling can

cause injury if the return electrode is malpositioned such that it contacts a small surface area, thereby creating an area of high current density that may inadvertently injure tissue. Unintentional direct coupling can also occur during laparoscopy through similar mechanisms, such as by inadvertent coupling of current to the laparoscope lens that is also touching bowel. In this case the current will be coupled to the metal sheath of the scope and applied directly to the bowel, potentially resulting in serious injury. Laparoscopic and robotic instruments typically have insulation protecting the nonvisible portion of the instrument; however, it is important to remain vigilant as insulation failure can occur as a result of forceful manipulation or manufacturing defects and result in potentially devastating injury.

Capacitive coupling occurs when a conductor (metal device or tissue) is in parallel with an active electrode but is not in direct contact. This results in the electrode inducing current within the other conductor, the magnitude of which depends on the proximity and level of insulation between the electrode and the conductor. Again, the degree of tissue damage is dependent on the current density applied. An illustration of this concept can be seen with the use of metal robotic trocars. A monopolar current traveling through a robotic arm within a metal trocar will induce a current in the metal trocar. This is normally harmless as the large contact area between the metal trocar and the abdominal wall minimizes current density. The greatest risk of injury occurs when a metal trocar is placed through a plastic outer trocar. In this scenario, the metal trocar is insulated as it passes through the abdominal wall and any area of contact, such as with bowel, will have a very high current density resulting in likely injury. To avoid such injuries it is imperative to ensure that all metal trocars are well "grounded," meaning they have a large area of contact with the skin and are not passed through insulating trocars[13] (Figs. 30.2, 30.3, 30.4).

Bipolar current is another popular form of electrosurgery in which the current is applied to the target tissue

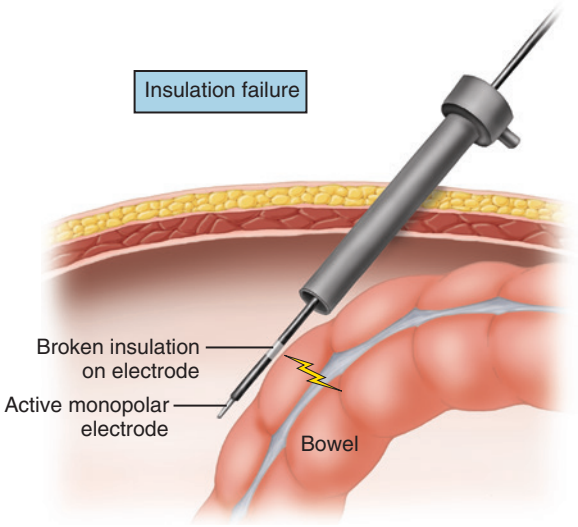


Figure 30.3 Insulation Failure. Except for the working element, monopolar laparoscopic instruments conduct along the entire device. Manufacturing malfunction or forceful use can cause a break in the layer of insulation. If this area comes in contract with tissue, current will be applied to that tissue unintentionally.

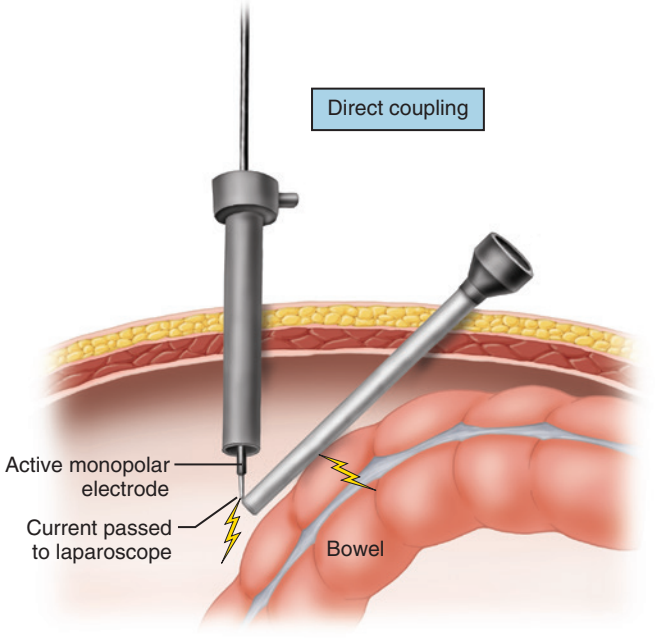


Figure 30.2 Direct Coupling. In the same way that in open surgery a current is applied to a forceps by touching the electrode to the metal instrument, the current can be directed to a metal object such as the laparoscope. This occurs when an active electrode comes in contact or near contact with a metal object, and that metal object touches tissue.

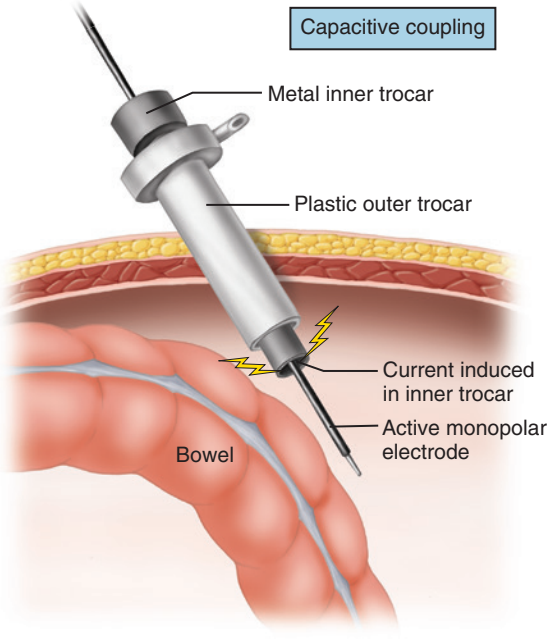


Figure 30.4 Capacitive Coupling. The risk of this effect can best be demonstrated when the current is being passed through a laparoscopic instrument that is within a metal trocar within an outer plastic trocar. Even without direct contact, the current will be induced in the metal trocar and insulated from the return electrode by the plastic electrode. If that metal trocar comes in contact with tissue the current can be applied to that tissue.

Table 30.2 Comparison of Electrosurgical Instruments

Device	Type of Technology	Tissue Temperature	Thermal Spread	Vessel Sealing	Note
Bovie	Monopolar	200–400°C	Variable	Variable	Return electrode
Bipolar	Bipolar	>100°C	2–22 mm	Variable	No return electrode
Harmonic scalpel	Ultrasonic	80°C	1–4 mm	5 mm	Best ability to cut, fastest to use
ENSEAL (Ethicon)	Impedance controlled bipolar + mechanical compression	~100°C	1.1 mm	7 mm	Very large seal strengths of vessels
LigaSure (Covidien)	Impedance controlled bipolar + mechanical compression	~100°C	1.8 mm	7 mm	Minimal charring
PK Trissector (Olympus)	Pulse controlled bipolar	~100°C	6.3 mm	7 mm	Intermittent tissue cooling creates uniform coagulation

positioned between two electrodes in close proximity. The return electrode (grounding pad) is not necessary as the bipolar current does not pass through the patient's entire body. It is a potentially safer form of electrosurgery as there is no potential for capacitive coupling and return electrodes are unnecessary.[58] Traditional bipolar instruments were limited by their inability to divide tissue since the necessary voltages cannot be safely delivered. However, there are now multiple commercially available devices that overcome this limitation through the use of bipolar current with real-time impedance feedback coupled with mechanical compression and/or blade transection. The LigaSure (Covidien), ENSEAL (Ethicon), and PK Trissector (Olympus) are examples of such devices. PK technology is unique in that it uses pulsed bipolar energy, which allows for intermittent cooling of the tissue. These more advanced bipolar devices use impedance detection that senses when adequate current has been applied and mechanical compression. This permits use of a lower voltage thereby minimizing thermal spread and allowing ligation of larger blood vessels (see Table 30.2). These devices are a safe alternative to suture ligation, but the added cost might not be offset by operative time saved.[59] It is critical to maintain tension-free mechanical compression for these devices to work properly.[60]

Ultrasonic technology, such as the "harmonic scalpel," has become very popular in laparoscopic surgery. These instruments do not pass electrical current through tissue and instead use an ultrasonic "blade" that generates mechanical energy and heat to coagulate blood vessels and divide tissue. Vessels up to 5 mm can be sealed but 2–3 mm is considered safer.[60] The vibrating of the blade tip produces pressure changes that vaporize cellular water allowing dissection at a much lower temperature (50–80°C) compared to electrosurgical techniques, thereby minimizing char and thermal spread to surrounding tissues (Table 30.2). Unlike electrosurgical instruments, it is important to remember that the blade of the harmonic scalpel remains hot between uses and injury can occur if the instrument comes in contact with tissue unintentionally. Because of this care must be taken when alternating between hot and cold dissection. The disadvantage of the harmonic scalpel is increased disposable cost and a limited ability to seal vessels larger than 5 mm. The surgeon may also have to alter his or her technique when using this instrument.

The Thunderbeat device (Olympus) combines bipolar and harmonic energy to obtain the cutting benefits of ultrasonic technology with the coagulation benefits of bipolar. While initial studies praise this technology for versatility compared with the other instruments tested with faster dissection speed, similar bursting pressure, and acceptable thermal spread, it is a relatively new device and comparative studies are lacking.[61,62]

The argon beam coagulator is a device that has many applications in open surgery; however, it is not suitable for laparoscopic and robotic surgery. This device works by passing a monopolar current through an ionized argon gas creating a plasma beam. The device expels a significant amount of gas and will not function properly in a pressurized environment such as an insufflated abdomen. There are reports of argon gas emboli associated with its use in laparoscopy. If it is absolutely necessary to use the argon beam coagulator, a port should be vented during its use[63] (see Table 30.2).

Monopolar electrical current poses a risk to patients with implanted electrical devices such as neuromodulators, intrathecal pumps, cardiac pacemakers, or defibrillators. These devices are susceptible to electromagnetic interference depending on the location of the electrodes, the pathway of current, and the power and type of current. As electrosurgical current passes through the patient from electrode to electrode (i.e., from hand-held instrument to grounding pad) the risk of interference is lowest when the device is father away from the path of current. In pelvic surgery, a monopolar current is felt to be safe in patients with implanted cardiac devices if the return is placed on the lower extremity as the current travels through the patient from the pelvis to the lower extremity and away from the device. The surgeon should be aware that the wire that connects the instrument to the generator carries a current and thus emits electromagnetic interference. The cord should be placed in the location opposite the implanted device. That is, if the patient has a cardiac device, the wire should be coming from the patient's feet. If the situation allows, bipolar current or ultrasonic energy is preferable as these modalities do not transmit current through the patient. If this is not possible, the lowest power needed to successfully complete the case should be utilized recognizing that coagulation current generates more interference than cutting

Table 30.3 Summary of Randomized Controlled Trials Comparing Commonly Employed Methods of Initial Laparoscopic Access[81–83]

Vascular Injury

			Open		Closed		
	Techniques Compared	**Study Author, Year**	*Events*	*Total*	*Events*	*Total*	**Peto OR (95% CI)**
	Open vs closed	–	–	–	–	–	–
	Open vs direct trocar	Angioli, 2013	0	107	0	187	n/a
	Open vs Veress	Angioli, 2013	0	108	0	193	N/A
		Peitigen, 1997	0	26	0	24	n/a
		Cogliandolo, 1998	0	75	1	75	0.14 (0–6.82)

			Direct		Veress		
			Events	*Total*	*Events*	*Total*	
	Direct trocar vs Veress	Agresta, 2004	0	275	0	323	
		Angioli, 2013	0	187	0	193	
		Inan, 2014	0	30	0	30	
		Karaca, 2014	0	200	3	200	0.13 (0.01–1.30)
		Prieto-Diaz-Chavez, 2006	0	42	3	42	0.13 (0.01– 1.27)

Visceral Injury

			Open		Closed		
	Techniques Compared		*Events*	*Total*	*Events*	*Total*	**Peto OR (95% CI)**
	Open vs closed	–	–	–	–	–	–
	Open vs direct trocar	Angioli, 2013	0	107	0	187	n/a
	Open vs Veress	Peitigen, 1997	0	26	0	24	n/a
		Angioli, 2013	0	108	1	193	0.21 (0–12.51)
		Cogliandolo, 1998	1	75	1	75	1.00 (0.06–16.14)

			Direct		Veress		
			Events	*Total*	*Events*	*Total*	
	Direct trocar vs Veress	Agresta, 2004	0	275	0	323	n/a
		Angioli, 2013	0	187	1	193	0.14 (0–7.04)
		Inan, 2014	0	30	0	30	n/a
		Karaca, 2014	1	200	0	200	7.39 (0.15–372.4)

(Adapted from "Laparoscopic entry techniques (Review)," The Cochrane Collaboration.)

current. Additionally, the implanted device should be evaluated pre- and postoperatively to check for error codes and ensure proper functioning. [64]

Mechanical Failure

The performance of laparoscopic surgery is dependent on the use of devices that are subject to mechanical failure, and the laparoscopic surgeon must be prepared to manage such failures.[65] There is a significant body of literature related to hemorrhagic complications following the use of surgical clips to ligate the renal vasculature during living donor nephrectomy. These studies concluded that nonlocking clips should not be used on the renal hilum as they were more likely to be involved in fatal arterial hemorrhage when compared to vascular staples and locking clips.[65] Given these data, locking clips (e.g., Hemo-o-loc Teleflex Medical) have been a mainstay of hilar control during laparoscopic nephrectomy since their introduction. However, in April of 2005, the manufacturer issued a contraindication for renal artery ligation during donor nephrectomy due to concern for clip failure. Shortly thereafter, in 2008, a multi-institution retrospective study of the locking clip in

1695 laparoscopic nephrectomies, including 486 donor nephrectomies, reported no clip failures on the renal artery and concluded that prior failures were likely related to poor application.[66] This is especially relevant for donor nephrectomy, as the transplant surgeon is attempting to preserve as much length on the renal artery as possible. Techniques to improve safety when using locking clips include applying multiple clips, leaving a 1- to 2-mm vascular cuff, keeping tissue in the center of the clip while avoiding tissue in the locking mechanism, visualization of the locking mechanism around the completely dissected vessel before closure, and use of appropriately sized clips.[67] If used correctly, self-locking clips are felt to be a safe mechanism for securing the renal hilum.

The endoscopic gastrointestinal anastomosis (Endo GIA) stapler is ideal for controlled ligation and division of large vessels such as the renal artery and vein and is widely, safely, and effectively used for this purpose.[67] However, failures do occur, with retrospective reviews reporting the incidence of stapler malfunction at 0.2–1.7%.[68] Most malfunctions are not due to device failure, but rather inappropriate use such as attempting to staple through a titanium clip, locking clip, or over another staple line. These failures may be avoided by adequate dissection and use of a harmonic scalpel or advanced bipolar device in regions where staple use is anticipated (e.g., during hilar dissection). Another cause of failure is adjacent tissue entrapment in the sliding mechanism on the lateral aspect of the stapler. If staple failure does occur the surgeon has to make the decision whether to open or proceed laparoscopically.[69] If a malfunction occurs during firing, the stapler should be left in place and a second stapler or locking clip should be used to obtain proximal control. Having multiple 10/12-mm ports is recommended to allow for more flexibility when using the stapler.

Visceral Injuries

Visceral injuries are rare events during laparoscopy, but can carry a high rate of morbidity and mortality. Of the abdominal viscera the bowel is most commonly injured, with a recent meta-analysis of the gynecologic literature reporting the incidence of bowel injury during abdominal laparoscopy at 0.13%. The small bowel is more likely to be injured followed by the colon. In the same series, bowel injury occurred most commonly during initial laparoscopic access (55%) and during electrosurgical dissection (29%). Less commonly, injury occurred during lysis of adhesions or with bowel graspers.[70] These trends are mirrored in the urologic literature.[71]

The incidence of rectal injuries in laparoscopic robotic surgery is about 0.2%. Historically these were treated with proximal diversion, but primary repair without a diverting colostomy is advocated in most cases. It has been reported that the overall percentage of colostomy applied in cases with rectal injury was only 32%.[72] A recent review noted that while mechanical bowel preparation may reduce the technical difficulty of the operation, it did not have a beneficial impact on the likelihood of injury or need for a diverting colostomy associated with rectal injury during radical prostatectomy.[72]

If recognized intraoperatively bowel injuries can be managed laparoscopically, but the surgeon should always consider conversion to laparotomy if this will enable superior repair.[70] Minor bowel injuries may be repaired primarily, but bowel resection and enteric diversion may be necessary for extensive injuries. When assessing a potential injury the anterior and posterior wall of the bowel should always be inspected to evaluate for through-and-through injury. If there is any question of bowel injury, an intraoperative general surgery consultation is recommended. It is also important to realize that assessing the true degree of electrosurgical injury is challenging in the acute setting as the extent of thermal injury is oftennot immediately apparent. It is possible that the coagulation effects of electrosurgery may temporarily seal off a perforation, making intraoperative recognition more challenging.

Up to 75% of bowel injures during laparoscopy are unrecognized intraoperatively and are diagnosed 4–10 days after surgery.[60] Clinical signs of bowel injury include severe abdominal pain localized to a single trocar site, abdominal distention, diarrhea, and leukopenia followed by acute cardiopulmonary collapse secondary to sepsis. It is notable that these signs, particularly localized abdominal pain and leukopenia, differ from the classic description of perforated viscus and may cause diagnostic confusion and delay.[73] If there is clinical concern for bowel injury, axial imaging with oral contrast should be immediately obtained. Note that free air is not a reliable sign, as it is typical for recent abdominal surgery. With any major abdominal organ injury, it may be advisable to consult a general surgeon to ensure appropriate evaluation and management.

Solid organ visceral injuries, including those to the liver, spleen, or pancreas, may occur during laparoscopic surgery. Injuries to the liver are usually due to retraction during right-sided renal or adrenal procedures. Careful lysis of hepatic adhesions should be performed prior to placing liver retraction.[74] Injuries to the liver and spleen can typically be managed conservatively with application of direct pressure, use of coagulation current, and/or application of hemostatic agents. While data regarding iatrogenic splenic injury during laparoscopy are limited, blunt splenic injury is well studied and many of the principles of management extrapolated. Splenectomy is rarely necessary, and delayed postoperative splenic bleeding can be managed with splenic artery embolization. If splenectomy is necessary it can be achieved laparoscopically if the surgeon is comfortable with the approach.[75] Pancreatic injury may also occur, most commonly following left-sided laparoscopic renal and adrenal surgery. The overall incidence of pancreatic injury in laparoscopic surgery is around 0.2%, but is estimated at 2–8% during left-sided renal and adrenal surgery, particularly in the setting of large renal and adrenal masses that may distort pancreatic and retroperitoneal anatomy and increase the likelihood of injury.[76] If injured, the tail of the pancreas can be safely ligated and transected with the Endo GIA stapler. In this setting, a drain should be left and amylase and lipase levels in the drainage fluid can be followed postoperatively. Unrecognized pancreatic injury can lead to severe morbidity, and a high index of suspicion is necessary in patients with prolonged ileus and abdominal pain. These patients should be evaluated with serum amylase levels as well as axial imaging if clinical concern warrants.

Bladder injuries can likewise occur with dissection or access, and their management is similar to that of traumatic injury. Bladder injury should be considered when gross hematuria suddenly develops or when the Foley drainage bag inflates with gas. Veress needle injuries can be managed conservatively with or without Foley catheter drainage. By definition, if direct injury occurs during transperitoneal laparoscopy the injury is intraperitoneal and primary repair and Foley drainage should be undertaken. If cystorrhaphy is required, it should be performed with an absorbable suture and a drain should be left. If bladder injury is uncertain, methylene blue dyed saline can be injected retrograde through a Foley catheter to identify a bladder perforation. Potential for ureteral injury may be evaluated by monitoring for efflux of dyed urine following intravenous administration of either indigo carmine, methylene blue, or floroscein; or by retrograde pyelography.

Pleural/Diaphragmatic Injury

Pleural and diaphragmatic injury can occur during laparoscopic dissection of the adrenal gland or the upper pole of the kidney with an estimated incidence of 0.6%.[77] Unlike in open surgery, the use of pneumoperitoneum during laparoscopy can increase the likelihood of pneumothorax, even with a small pleural injury. Even if the pleural injury is not directly visualized, the surgeon may detect an injury by noting loss of the normal concavity of the diaphragm as it billows downward.[78] The patient may also develop elevated airway pressures, higher end-tidal carbon dioxide, and decreased oxygen saturation. These injuries may be managed laparoscopically by oversewing the pleurotomy and evacuating the insufflate from the thoracic cavity. This is accomplished by the anesthesiologist expanding the patient's lungs to vital capacity (breath hold at end inspiration) as the sutures are tied down. If the patient becomes unstable intraoperatively, pneumoperitoneum must be immediately vented and needle or tube thoracostomy may also be necessary. Interventional radiology–placed tube thoracostomy is a treatment option for persistent symptomatic pneumothorax postoperatively.[74]

Conclusions

As the role of laparoscopy in urology continues to expand it is essential that the urologist understand the complications unique to these operations and be expert in their management. In this chapter we discussed the importance of appropriate selection of patients for laparoscopic surgery, unique anesthetic risks, and techniques to avoid positioning-related nerve injuries during surgery. Techniques of laparoscopic access were reviewed with emphasis on the truth that no access method is entirely without risk of vascular or visceral injury and the laparoscopic surgeon must be facile with multiple methods in order to perform safe and effective surgery. Key principles of fundamental technologies such as electrosurgery were explained and their applications to novel devices were presented. As technology continues to evolve it is essential urologists remain at the forefront of innovation by safely incorporating these techniques into their practice.

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Chapter 30 Questions

1. During a laparoscopic left nephrectomy, which of the following should NOT be used on the hilum?
   a. Hem-o-loc clip
   b. Titanium nonlocking clip
   c. Endo GIA stapler
   d. Suture ligation after conversion to open surgical approach
   e. None of these are safe

2. Three hours into a robotic assisted laparoscopic prostatectomy, the anesthesia assistant informs you the patient's ventilation has become more difficult and that high positive pressure ventilation is required. The patient is currently stable. Airway sounds, end-tidal CO_2, and oxygen saturation levels are normal. What is the most appropriate first step to reduce the elevated ventilation pressures?
   a. Decrease the pneumoperitoneum to 15 mm HG
   b. Place a chest tube
   c. Abort the procedure
   d. Convert to open prostatectomy
   e. Using the robot, incise the diaphragm to release pressure

3. During a left laparoscopic nephrectomy, the diaphragm can be seen billowing and a pleurotomy is seen. What is the next best step in management?
   a. Consult surgery to place a chest tube
   b. Convert to open procedure as pneumoperitoneum will cause a pneumothorax
   c. Nothing; pleurotomies are common and require no intervention or assessment
   d. Close the pleurotomy with an absorbable suture with the breath held at end inspiration
   e. Close the pleurotomy with an absorbable suture with the breath held at end expiration

4. A patient has an implanted pacemaker and is scheduled for a laparoscopic nephrectomy. All of the following are recommended EXCEPT:
   a. Place the grounding pad directly over the pacemaker to decrease current density
   b. Use bipolar or ultrasonic energy if possible
   c. The monopolar instrument's wire should be directed off the field toward the feet
   d. Evaluate the pacemaker before and after surgery
   e. Use as low a wattage of monopolar current as the case allows

5. A 72-year-old obese patient with poorly controlled type 2 diabetes undergoes a 12-hour, robotic-assisted laparoscopic cystoprostatectomy with ileal conduit diversion. On postoperative day 2, the patient becomes oliguric with tea-colored urine without clots. Labs demonstrate creatinine of 3.4 and CK of 96,000 IU/L. What is the next step in evaluation and/or management of this situation?
   a. Consult nephrology
   b. CT abdomen and pelvis without contrast
   c. Order dose of furosemide
   d. Obtain urine electrolytes and calculate fractional excretion of urea
   e. Perform a thorough upper and lower extremity exam

6. According to a recent Cochrane Collaboration review, which of the following methods of primary laparoscopic entry is least likely to result in vascular injury?
   a. Veress
   b. Hassan
   c. Direct trocar entry
   d. Direct entry with visual obturator
   e. Placement of hand assist gel port

7. What is the most commonly injured vascular structure during laparoscopy?
   a. Inferior vena cava
   b. Superior mesenteric artery
   c. Left iliac artery
   d. Right iliac artery
   e. Distal aorta

8. Which methods can be used to obtain hemostasis following inferior vascular artery laceration?
   a. Incision extension and direct suture ligation
   b. Direct pressure applied by using adjacent trocar
   c. Tamponade applied via transabdominally placed Foley catheter
   d. Transabdominal suture ligation using Carter-Thommason device or Keith needle
   e. All of the above

9. Which of the following is NOT a clinical sign of postoperative bowel injury?
   a. Severe abdominal pain localized to a single trocar site
   b. Abdominal distention
   c. Fever
   d. Leukocytosis
   e. Diarrhea

10. Injuries to the peroneal nerve are most likely to result from:
    a. Excessive external rotation of the hip
    b. Prolonged lithotomy position
    c. Excessive knee extension
    d. Inadequate padding of the lateral knee
    e. b and d

Answers

1. **b.** It is not recommended to use a nonlocking clip on the renal hilum. While there is a black box warning for locking clips, studies show that they are safe when used correctly.
2. **a.** The pneumoperitoneum is the likely factor creating high positive pressure ventilation. Reducing the pneumoperitoneum and returning the patient to a supine position will likely improve ventilation pressure. Aborting or converting to open surgery is not indicated at this point. A chest tube is not necessary because there

is no evidence of a pneumothorax. An intentional diaphragmatic injury is not indicated.

3. **d.** A pleurotomy should be addressed. The initial management is to repair the pleurotomy with an absorbable suture once the air is evacuated from the chest with a held deep inspiration. Converting to an open procedure or placement of a chest tube should not be done unless the patient becomes hemodynamically unstable.
4. **a.** Monopolar current is not contraindicated for patients with implanted electronic devices. It is recommended to place the return electrode far away from the device, to use nonmonopolar current if possible, and to use as low a wattage as the case allows. The wire from a monopolar instrument can cause interference and should be directed away from the implanted device. The device should also be evaluated before and after surgery.
5. **e.** This patient has developed rhabdomyolysis, and urgent intervention is required. The patient needs vigorous hydration and urinary alkalinization, but a thorough upper and lower extremity exam should be performed immediately. This patient is at risk of compartment syndrome. If his compartments are firm, compartment pressures should be obtained and orthopedic surgery should be consulted for a possible fasciotomy. A nephrology consult may be necessary but is not the first step. A CT scan is not needed to confirm the diagnosis. Furosemide is not indicated. Fractional excretion of urea will not help confirm the diagnosis of rhabdomyolysis and is inaccurate in patients with urostomy.
6. **c.** In a systematic review of five RCTs comparing direct trocar entry with Veress technique, the Cochrane Collaboration reported a lower incidence of vascular injury with the direct trocar access. There was no reported difference in the incidence of visceral injuries. It should be noted that the included studies were all of either "low" or "very low" quality.
7. **e.** According to a large review of vascular injury during gynecologic lapasroscopy, injury to the distal aorta was most common (25%), followed closely by the right common iliac artery (21%). It is important to remember that injury to any vascular structure is possible and injury is most common while obtaining initial laparoscopic access.
8. **e.** All of the listed techniques are valid means to obtain hemostasis following injury to the inferior epigastric artery. During management of such injuries, it is reasonable to attempt to tamponade initially; however, if bleeding is persistent, suture ligation will be definitive.
9. **d.** It is notable that the signs of bowel injury following laparoscopy differ compared to classically described signs of perforated viscus. These signs include those listed above as well as leukopenia. In situations where occult bowel injury is suspected, axial imaging with oral contrast should be obtained immediately.
10. **e.** The peroneal (fibular) nerve courses laterally to the head of the fibula where it is vulnerable to compression injury in lithotomy position when the lateral aspect of the knee is inadequately padded. These injuries present with parasthesia over the lateral foot and inability to dorsiflex the foot. In order to minimize the risk of such injuries it is imperative to ensure the weight of the leg is concentrated in the heel, external rotation of the hip is minimized, and the region of the peroneal nerve is well padded.

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31 Special Considerations in Robot-Assisted Surgery

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CHAPTER OUTLINE

Introduction
Patient Selection and Preparation
Robotic-team Approach
Patient Positioning
Effects of Pneumoperitoneum
Team Communication
Robotic System Failure
Conclusions
Chapter 31 Questions and Answers

KEY POINTS

1. The surgeon should convey all possible risks and benefits associated with a specific robotic procedure during informed consent, as well as clearly conveying the possibility that the operation may involve conversion to the traditional laparoscopic or an open approach.
2. The basic aim of patient positioning is to allow for maximal access to the surgical target organ without compromising patient safety. Compression-associated peripheral neuropathies are associated with compression of pressure joints, use of shoulder braces, longer operative times, and prolonged Trendelenburg positioning.
3. With pneumoperitoneum, intraabdominal pressure rises and, as a result, can have various end-organ implications, including an increase in both the heart rate and systemic vascular resistance secondary to compression of the intraabdominal aorta and carbon dioxide-mediated sympathetic stimulation.
4. The use of intermittent pneumatic compression (IPC) in Robotic and minimally invasive surgery is recommended by the American Urologic Association to assist with VTE prophylaxis.
5. Passage of laparoscopic instruments outside the console surgeon's field of view can potentially result in damage to visceral organs and blood vessels; thus, laparoscopic instruments should be localized in the body under direct vision, and the bedside surgeon should recognize and memorize the spatial path of the instrument to the target surgical area for subsequent insertion.

Introduction

Robot-assisted laparoscopic surgery has radically changed the landscape of minimally invasive surgery during the past 15 years. Its advantages over traditional laparoscopy include a superior magnified, stereoscopic three-dimensional view, 7 degrees of freedom, no fulcrum effect, and improved surgeon ergonomics. This chapter explores the special considerations surgeons must bear in mind while performing robotic surgery.

Patient Selection and Preparation

The preoperative assessment prior to any robotic surgical procedure begins with a thorough patient history and physical examination. All pertinent laboratory workup and radiologic imaging should be thoroughly reviewed with the patient. Medically complex patients with significant cardiac or pulmonary comorbidities should be referred to medical specialists for operative risk stratification and optimization. A satisfactory informed consent should be obtained, informing the patient of the possible risks and benefits associated with the procedure, as well as clearly conveying the possibility that the operation may involve conversion to the traditional laparoscopic or an open approach. A variety of upper and lower urinary tract procedures can be approached robotically, depending on the surgeon's experience. Specific contraindications to general transabdominal urologic robotic surgery are similar to laparoscopic surgery and include extensive previous abdominal/pelvic surgery or radiation, as well as severe medical comorbidities precluding an operation, such as uncorrectable coagulopathy, severe cardiopulmonary disease, or multiorgan failure. Anatomic anomalies, body habitus, and the specific surgical procedure must be considered when selecting the appropriate robotic surgical system. The da Vinci Xi system (Intuitive Surgical Inc., Sunnyvale, CA) is preferable for multi-quadrant procedures.

Robotic-team Approach

An experienced robotic team is critical to the success of an operation. The sophisticated robotic technology requires a coordinated approach for proper setup of the operating room. A surgical checklist should be conducted to ensure that all pertinent equipment is available and functioning before the start of a case. Prior to the patient's entrance into the operating room, all critical parts of the da Vinci surgical system, including the surgeon console, patient-side cart, and instrumentation (its associated remaining uses and proper insulation properties), as well as the audio-visual connections, should be deemed functional. Furthermore, particular procedures demand specific positioning of the robotic patient-side cart, anesthesia equipment, and instrument table in relation to the operating table. In addition, some procedures require specific intraoperative equipment; for example, if a procedure is expected to necessitate intraoperative real-time ultrasound, then the surgical team must ensure proper function of the TilePro (Intuitive Surgical Inc., Sunnyvale, CA); this involves the digital output cable from the ultrasound machine being connected to the digital video interface (DVI) or S-video input of the robotic da Vinci console.[1]

Patient Positioning

The basic aim of patient positioning is to allow for maximal access to the surgical target organ without compromising patient safety. For lower urologic tract surgery, such as robotic-assisted laparoscopic radical prostatectomy (RARP) or robotic-assisted laparoscopic cystectomy (RARC), the patient's arms are secured at the sides and lower extremities are placed in low lithotomy position using Yellofins elite stirrups with Lift-Assist (Allen Medical, Acton, MA) with careful attention paid to avoiding undue hip abduction, flexion, and extension (Fig. 31.1). All pressure points should be carefully padded with care. The patient should then temporarily be placed into a steep Trendelenburg position between 25 and 45 degrees in order to test whether respiratory compliance and effort is tolerated in this position. For robotic transperitoneal renal surgery, our preference is to place the patient in a modified lateral decubitus position (i.e., 45-degree partial flank position) (Figs. 31.2–31.4) and to rotate the table laterally to achieve roughly a 90 degree angle in relation to the floor. In this position, gravity assists with medial mobilization of the large and small bowel. At the beginning of the surgery, in most patients, we rotate the patient to a supine position to establish pneumoperitoneum in the umbilicus. After insertion of the midline trocars, the patient is rotated to a 90-degree lateral position for the rest of the operation. In morbidly obese patients, umbilical and midline trocars are avoided and pneumoperitoneum is obtained laterally. The patient's ipsilateral arm is padded and taped alongside the chest and abdomen so that it does not interfere with the robotic cephalad arm. The patient's



Figure 31.1 Appropriate positioning for robotic prostatectomy.



Figure 31.2 Appropriate positioning for robotic renal surgery in partial flank position.

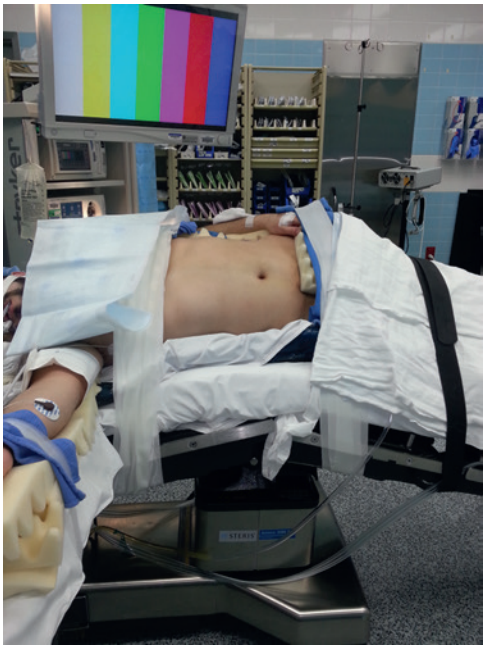


Figure 31.3 Appropriate positioning for robotic renal surgery in partial flank position with ipsilateral arm secured in an adducted position at the hip.



Figure 31.4 Appropriate positioning for robotic renal surgery in full flank position with ipsilateral arm secured in a cephalad position.

bottom leg is flexed while the top leg is extended. Adequate padding is essential and placed at all pressure points. The table is mildly flexed to increase the angle between the costal margin and iliac crest, thereby increasing lower abdominal space to utilize a 4-arm robotic approach. For the robotic retroperitoneal renal approach, similar to traditional open renal surgery, the patient is placed in a full lateral decubitus position, and a sub-axillary roll is used to help prevent brachial plexus injuries. Furthermore, the table is flexed fully to allow for maximum retroperitoneal working space.

Long operative periods in these exaggerated positions predispose the patient to various position-related complications, including ocular manifestations, facial and laryngeal edema, various neuropathies, compartment syndromes, rhabdomyolysis (RM), deep venous thrombosis, and deficiencies in skin integrity.[2]

A recent large, national population-based sample of patients undergoing open and robotic procedures reviewed the rates of eye-related complications. The data revealed that robotic hysterectomy carried a 6.5 times greater risk of experiencing a corneal abrasion than with the open approach; however, there was no statistical difference in corneal abrasion when open prostatectomy patients were compared to robotic prostatectomy patients.[3] Several purported risk factors for corneal abrasions include raised intraocular pressure secondary to prolonged, steep head-down position, corneal exposure and dryness, and mechanical trauma; in this study, African American race served to be a protective factor. Wen et al.[4] conducted an analysis of another large, national inpatient sample of patients who underwent open, laparoscopic, and robotic-assisted prostatectomies and compared the position-related complication rates between them. This study of 175,699 men revealed an overall complication rate of 0.79%, with ocular-related complications (visual disturbances, unilateral eye blindness, and corneal-foreign bodies) being the most common (51% of total complications). The remainder of injuries (49%) were related to nerve lesions, RM, and compartment syndrome. Undergoing a laparoscopic prostatectomy (OR = 2.88) and having multiple comorbidities (OR = 2.34) conferred the greatest statistically significant risks of experiencing a positional injury. In contrast, the robotic approach was not associated with developing a higher rate of position-related complications when compared to the open procedure. Overall ocular complications as well as visually threatening eye complications (i.e., visual loss) proved to be more common in the open group versus the robotic cohort. Development of a positioning complication was found to have a resultant threefold increase in length of stay and fourfold increase in inpatient costs when compared to not incurring a position-related event. The authors conveyed surprise in their analysis of these data, as they initially hypothesized that robotic prostatectomy would carry an increased risk of positioning complications compared to the open approach, resulting from a greater operative length, an association revealed in previous studies.[5–7] Although this study was not able to account for operative times, its large national sample size suggests generalizable results.[4]

Positioning injuries involving the extremities include brachial plexus injuries as well as peripheral neuropathies. In the Trendelenburg position, inadvertent movement of the patient via gravity is possible; this is especially prone to occur in the obese patient population and can result in neuropathies and potential robotic port site abdominal injuries, incisional widening, and increased postoperative port site pain, as the patient shifts downward on the operating table while the robotic trocars remain in a stationary position.[2,8] Thus, various surgical immobilization mechanisms have been used to help prevent the patient from sliding downward. Shoulder braces have been identified in several retrospective reviews as a risk factor for brachial plexus injury via compression or stretch,[4,5,9–11] especially with concomitant abduction of the upper extremities to 90 degrees or greater.[10,11] However, Gainsburg et al. reported no evidence of brachial plexus injury on 575 consecutive RARP patients with the careful application of a horseshoe-shaped shoulder immobilization restraint around the acromio-clavicular joints in patients with a weight greater than 75 kg. Chest straps have also been used to prevent downward shifting of the patient while in steep head-down position; however, this has been shown to further decrease lung compliance and ease of ventilation.[12] Anti-skid foam pads secured to the surgical bed or bean bags are also utilized in some centers with success.[5,13]

Lower extremity peripheral neuropathies can manifest with postoperative pain, weakness, and sensation deficits/alterations and are thought to be caused by protracted flexion, abduction, and external rotation of the hip joints, or by compression of pressure points.[14] Operative lengths greater than 2–4 hours in the lithotomy position have proved to be a risk factor for the development of lower extremity neuropathies.[14–16] Interestingly, a higher BMI is proposed to be a protective factor against compression-related neuropathies.[14,15] The incidence of lower extremity neuropathies appears to be less than 2% in urologic robotic-assisted pelvic surgery; Manny et al.[17] report an incidence of lower extremity neuropathy of 1.7% in patients undergoing RARP or RARC while Koc et al.[14] report an incidence of 1.3% in their series of RARP patients. Furthermore, Warner et al.[15] performed an analysis on a series of 198,461 patients who underwent various surgical procedures in the lithotomy position and reported a 0.028% rate of lower extremity peripheral neuropathy (1 per 3608 patients) most commonly involving a motor neuropathy of the common peroneal nerve (78%). In contrast to the

lithotomy position, a split-leg position appears to pose a higher risk for femoral nerve palsy in performing RARP secondary to hyperextension of the hip joint to assist with docking of the patient-side cart.[14] Although a majority of peripheral neuropathies transiently improve several weeks to months postoperatively, some may persist longer and become permanent.[14–17]

Facial and laryngeal edema are other manifestations of a steep head-down tilt in lower urinary tract robotic surgery.[9] Facial congestion results from a protracted state of steep Trendelenburg position and can be minimized via limiting intravenous fluids during this portion of the procedure; it is important to replete the patient's intravascular volume prior to conclusion of the surgery. Laryngeal and pharyngeal edema is also implicated with lengthy Trendelenburg positioning, and extreme cases of this can result in respiratory distress occurring after a patient is extubated, necessitating reintubation.[8,18] Again, somewhat restrictive fluid management (less than 2000 mL) in the lithotomy position is thought to alleviate laryngeal edema.[9]

Postoperative RM and compartment syndromes of the gluteal muscles and lower extremities (well limb compartment syndrome, WLCS) resulting from robotic surgery are exceedingly rare complications and are associated with prolonged exaggerated flank or lithotomy positions.[19–23] Surgically induced RM is thought to result from prolonged compression of skeletal muscle associated with decreased blood flow, necrosis, possible compartment syndrome, and, ultimately, skeletal muscle breakdown, with subsequent release of myoglobin and creatine phosphokinase (CPK). CPK levels two to three times greater than normal in the proper clinical setting should alert the physician to a possible diagnosis of RM. Patients may experience tenderness at the site of injury, edema, muscle pain, and dark-colored urine, or may alternatively lack symptoms. Acute renal failure may result in 30–40% of patients and is thought to be mediated by reduced glomerular filtration, intratubular heme cast formation with subsequent obstruction, tubular obstruction by precipitated myoglobin, and a direct nephrotoxic effect via ferrihemate. Aggressive fluid hydration is recommended to produce a urine output of 200–300 mL/hour, and alkalanization of urine is recommended to prevent acute renal failure. Compartment syndromes warrant emergent consultation of orthopedic colleagues to perform fasciotomies.[22,24]

Pariser et al.[22] recently reported on a broad population-based sample of 1,016,074 patients undergoing major urological surgeries (prostatectomy, radical nephrectomy, partial nephrectomy, and radical cystectomy) in the largest study to date investigating risk factors for development of RM. This study revealed a 0.1% (870 patients) overall incidence of RM. Patients who underwent radical prostatectomy were least likely to experience postoperative RM; patients who underwent radical/partial nephrectomy and radical cystectomy had odds ratios of 2.66 and 3.69 (p values < 0.001), respectively, of developing RM when compared to radical prostatectomy patients. Independent risk factors for RM included males, younger patients, diabetes mellitus, obesity, preexisting chronic kidney disease, and perioperative bleeding. Minimally invasive surgery was not associated with RM. Operative times were not available for analysis in this national patient sample. Length of stay and total charges were significantly greater for the RM cohort. Furthermore, 66.3% of patients with RM developed acute kidney injury and experienced a 6.4% inpatient mortality rate. In another large, population-based study, Gelpi-Hammerschmidt et al.[25] analyzed the rates of RM following open, laparoscopic, and robotic extirpative renal surgery. The overall incidence rate of RM was exceedingly low at 0.001%; the robotic approach was associated with a greater than twofold higher risk of developing RM compared to laparoscopic surgery. Additional significant risk factors for RM included obesity, male gender, significant medical comorbidities, and operative time greater than 5 hours. Patients who experienced postoperative RM were more likely to suffer from other nonfatal complications as well as endure twice lengthier hospital stays. Deane et al.[26] measured mean pressures exerted on patients' skin during lateral decubitus positioning with different degrees of table flexion, kidney rest position, and operating table surfaces. Male gender (irrespective of BMI), BMI >25, table flexion (half flexion and full flexion compared to flat position), and kidney rest elevation (compared to nonelevation) were associated with higher interface pressures. Supplementary padding of the operating table with egg crate pad did not prove to significantly decrease interface pressures, while the addition of gel padding significantly increased the mean skin interface pressures by 1.61 mm Hg; thus, the authors concluded it is unnecessary to place extra protective material over the normal operating table mattress during renal surgery.

The prevalence of venous thromboembolism (VTE) events following robotic pelvic surgery has been described in the literature. In a recent multicenter analysis of a prospectively maintained LAPPRO (Laparoscopic Prostatectomy Robot Open) database, Tyritzis et al.[27] reported on the occurrence of VTE (i.e., deep venous thrombosis and/or pulmonary embolism) in their cohort of 3544 patients undergoing open radical prostatectomy (ORP) and RARP. Their results reveal an overall incidence of VTE in 18 cases (2.2%) in the ORP cohort and in 16 cases (0.6%) in the RARP group. Importantly, a significant eightfold increased risk of development of VTE was reported when lymph node dissection (LND) was performed. Overall, ORP was associated with a significantly higher (more than threefold) risk of experiencing a VTE when compared to RARP; however, there was no significant difference in VTE events when comparing ORP and RARP with concomitant LND. When LND was taken into account, ORP resulted in a significant more than threefold incidence of postoperative VTE compared to RARP. Independent risk factors for development of VTE included a history of thrombotic incidents, advanced stage disease (pT4), and a Gleason score of at least eight or higher. Liu et al.[28] reported similar overall rates of VTE following ORP (1.79%) and minimally invasive radical prostatectomy (0.82%) in their series of 5319 cases. Abel et al.[29] performed a retrospective single institution review of 549 consecutive patients undergoing RARP and reported an overall postoperative VTE incidence of 1.8%; significant predictors for VTE development included increased operative time, higher BMI, and blood transfusion. Prophylaxis with unfractionated heparin prior to incision was not associated with significantly lower VTE rates or significantly higher bleeding episodes. Secin et al.[30] reported an overall incidence of 0.5% (31 events) of VTE in a multi-institutional study that included 5951 patients undergoing minimally invasive radical prostatectomy (i.e., laparoscopic and RARP). Risk factors for VTE included history of thrombosis, smoking, increased operative time,

reoperation, length of hospitalization, and increased prostatic volume. Prophylactic use of heparin either prior to surgery or postoperatively was not significantly associated with VTE ($p = 0.7$); in fact, centers utilizing heparin prophylaxis had similar rates of VTE when compared to centers not incorporating heparin prophylaxis. Preoperative prophylactic use of heparin was associated with significantly higher intraoperative estimated blood loss ($p < 0.0005$) as well as longer hospitalization ($p < 0.0005$). LND did not represent a significant risk factor for VTE in this series. Other RARP series have reported similarly low (less than 2%) incidence rates of postoperative VTE.[31,32] Saily et al.[33] reported on bleeding and VTE rates with preoperative and inpatient postoperative heparin administration, as well as a 15-day postoperative outpatient course of an oral anticoagulant (dabigatran) in 400 consecutive RARP patients; overall, one patient (0.25%) developed VTE, and nine patients (2.3%) developed significant postoperative bleeding, with eight patients requiring transfusion.

The safety and use of pharmacologic prophylaxis (PP) for prevention of VTE in robotic renal surgery are sparse in the literature. A current National Surgical Quality Improvement Program (NSQIP) database revealed an overall low incidence rate of patients developing VTE after minimally invasive partial nephrectomy (0.23%) and radical nephrectomy (0.42%); in this study, the occurrence of VTE was associated with more than a 12-fold increase in readmission rates ($p = 0.001$).[34] Information regarding VTE prophylaxis was not provided in this national registry review. Recently, a large single institution retrospective review by Kara et al.[35] compared perioperative outcomes of a robotic partial nephrectomy (RPN) cohort of 984 patients, of which 222 patients received PP (subcutaneous heparin or enoxaparin) at any time (preoperatively or postoperatively) and 762 patients who did not receive PP. The incidence rates of postoperative VTE were not significantly different, with 1.8% in the PP group compared to 2.1% in the non-PP group ($p = 0.75$); likewise, the rates of adverse hemorrhagic events were also comparable, occurring with a frequency of 3.1% and 5.6% in the PP and non-PP groups, respectively ($p = 0.13$). A majority (93.3%) of VTE episodes occurred within 1 month and after hospital discharge; thus, the authors concluded that inpatient-only VTE prophylaxis did not help to prevent VTE, and that a lengthier regimen (30 days postsurgery) of outpatient PP should be considered in patients undergoing RPN, as based on prior randomized control trials that evaluated prolonged PP for VTE events in open surgeries.[36,37] At this time, the American Urologic Association recommends the use of intermittent pneumatic compression (IPC) in laparoscopic and robotic surgery as well as identification of high-risk patients who may benefit from VTE prophylaxis.[38]

Effects of Pneumoperitoneum

The various techniques in the establishment of pneumoperitoneum (i.e., Veress needle vs Hasson technique or other modified hybrid methods) and trocar placement and their potential complications (e.g., vascular injury/organ injury), as well as troubleshooting, are discussed extensively elsewhere in this text. Once establishment of peritoneal gas insufflation is successfully obtained, communication with the anesthesiology team becomes crucial when performing robotic surgery, as physiologic alterations are common. With pneumoperitoneum, intraabdominal pressure rises and, as a result, can have various end-organ implications. From a cardiovascular standpoint, both the heart rate and systemic vascular resistance increase secondary to compression of the intraabdominal aorta and carbon dioxide–mediated sympathetic stimulation.[39] Increased intraabdominal pressure places mechanical compression upon the inferior vena cava, causing decreased perfusion to the heart, ultimately resulting in reduction of cardiac output, especially in a hypovolemic hydration state. Of note, the reverse Trendelenburg position causes venous pooling of blood in the lower extremities, further reducing cardiac preload, while the Trendelenburg position serves to increase cardiac preload.[39–41] Pneumoperitoneum causes respiratory changes, including a reduction in functional reserve capacity (FRC), restricted diaphragmatic excursion, and predisposition to atelectasis. Placing the patient in a concomitant Trendelenburg position pushes the diaphragm cephalad, further reduces lung compliance, worsens ventilation–perfusion mismatch, and requires higher airway pressures to maintain a steady tidal volume.[42] An increase in intraabdominal pressure also has downstream consequences on renal perfusion and function. A decrease in renal blood flow as well as in renal function (as measured by urine output, GFR, and effective renal plasma flow) is a transient change expected during induction and duration of pneumoperitoneum.[43] In order to limit adverse hemodynamic and physiologic changes secondary to pneumoperitoneum, our preference is to maintain an insufflation pressure of 12–15 mm Hg or lower during our robotic procedures. In cases of venous bleeding or poor surgical exposure, the insufflation pressure can be transiently increased to 20 mm Hg.

Team Communication

Once pneumoperitoneum, strategic port placement, and patient-side cart docking is achieved, effective team communication between all members of the operating room continues to be critical as the primary surgeon transitions away from the operating table to the console to begin the robotic part of the procedure. The bedside surgeon becomes responsible for assisting the console surgeon with numerous tasks, including laparoscopic instrument passage, laparoscopic tissue retraction and manipulation, suction as well as irrigation of the surgical field, robotic instrument exchange, oversight of potential internal versus external robotic arm clashing, and maintenance of pneumoperitoneum. Passage of laparoscopic instruments outside the console surgeon's field of view can potentially result in damage to visceral organs and blood vessels; thus, laparoscopic instruments should be localized in the body under direct vision, and the bedside assistant should recognize and memorize the spatial path of the instrument to the target surgical area for subsequent insertion. The bedside surgeon should vocalize when passage of a laparoscopic instrument is impeded and withdraw and redirect its course under direct vision to avoid injury to surrounding structures. Similarly, although the patient-side robotic arms are designed to retain positional memory of the instruments inside the body during exchanges, the bedside assistant

should always locate the instrument under direct vision during re-entry, as bowel or other structures can inadvertently shift position into the path of reinsertion. Again, robotic instruments should never be forced against resistance, as significant intracorporeal damage can result; instead, the problem (e.g., inadvertent robotic port withdrawal from the peritoneum) should be identified via communication between the bedside and console surgeon and remedied in a coordinated manner. In the event of an emergent conversion to an open procedure, clear communication should occur between the console surgeon and all the members of the operating team; the bedside surgeon should expeditiously and safely remove all instruments from the body and undock the patient-side cart. Open instrumentation should be available for immediate use, and a plan for open incision should already be prepared.[44,45]

Robotic System Failure

Robotic system failures have been described in the literature. While no standardized method to report system malfunction currently exists, the United States Food and Drug Administration's (FDA) Manufacturer and User Facility Device Experience (MAUDE) database provides a vehicle that allows health-care professionals to voluntarily and anonymously report adverse events related to device failures or malfunctions that impact patient safety.

Friedman and Lendvay[46] performed the most recent analysis of da Vinci robotic instrument malfunction between 2009 and 2010 using the MAUDE database and detected a total of 565 instrument failures. They divided these into five categories of failures in the order of most to least common: wrist/tool-tip, cautery, shaft, cable, and housing failures. Wrist or tool-tip failures were the most frequently reported type of instrument failure accounting for 285 malfunctions; of these, 150 involved a fractured or otherwise broken jaw or tool tip, affecting 108 monopolar curved scissors. In a majority of these events, a tool tip fractured into the patient and was subsequently safely removed. Cautery failure was reported to be the second most common malfunction with 184 incidents; 174 of these events involved electrical failure, a majority (90%) of which included observed arcing or heat-damaged tissue and most commonly (125/174 events) involved monopolar curved scissors. The third most frequent type of instrument failure involved shaft dysfunction (76 events), including protective material fracturing off the shaft or cracked shafts (36 failures), observation of significant scratch marks on the shaft, or inadvertent material removal off the shaft (19 failures), as well as outright circumferential shaft breaks (eight failures). Cable malfunction accounted for the fourth most common type of instrument failure with 29 events; 28 of these incidents involved a frayed or fractured cable at the distal tool-tip side of the instrument. Lastly, the least common type of instrument failure involved seven incidents of housing malfunction, including two events where the instrument was unable to be extracted from the robotic arm, one incident of a defective instrument not registering despite having sufficient lives, one event where the cleaning tube was thrust into the housing, and the last failure involved jaws that failed to open and shut.

Lucas et al.[47] performed an earlier review of the MAUDE database between 2003 and 2009 and found a total of 1869 reported adverse events involving 991 pertaining to the da Vinci S (dVS) and 878 associated with the earlier da Vinci (dV) platform. Similar to Friedman's series, Lucas et al. also identified instrument failure to be the most common type of robotic malfunction, with 995 (74.2%) events occurring between 2007 and 2009 and 379 (72.3%) reported incidents between 2003 and 2006. The older generation dV system was associated with significantly higher rates of instrument fragmentation into the patient (27.8% vs 7.5%) and arcing (32.9% vs 12.7%). Reported failures associated with the robotic console and patient-side cart decreased significantly after 2007. Between 2007 and 2009, 71 (5.3%) console failures were reported, while 49 (9.4%) were identified between 2003 and 2006; similarly, 91 (6.8%) patient-side cart failures were cited between 2007 and 2009, while 57 (10.9%) were reported between 2003 and 2006. Furthermore, the dV platform was associated with significantly higher console and patient-side cart failures compared to the newer dVS system. Reported incidents of camera failures were comparable between the two systems. The rates of conversion to open procedures proved to be significantly lower over time while rates of aborted procedures increased over time. The authors also analyzed the association between system malfunction and patient outcomes. Robotic platform failures leading to patient injury did not change significantly between 2003 and 2008. Although the patient injury rate (24.1%) of 33 injuries resulting from 137 robotic failures was significantly higher in 2009 compared to previous years, it was thought to be artificially inflated secondary to incomplete data collection that year. Patient deaths were significantly increased in the years between 2007 and 2009 (1/16,000) when compared to between 2003 and 2006 (1/70,000). Once again, incomplete data collection in 2009 may have caused a falsely elevated rate; however, the authors also note that a willingness to tackle procedures of higher complexity may have also led to this finding. Andonian et al.[48] reviewed the MAUDE database between 2000 and 2007 and reported 189 adverse events related to robotic malfunction; they estimated an overall device failure rate of 0.38%, provided that about 50,000 robotic procedures had been performed during that time period.

Although the MAUDE database provides an effective tool for reporting device-related adverse events, it also poses significant limitations, as reporting to the database is completely voluntary and thus prone to underreporting of adverse robotic system failures.[47]

Buchs et al.[49] performed a single institution retrospective review of a prospectively maintained database of 526 consecutively performed general surgery procedures. Overall, 18 cases (3.4%) of device failure were identified. Of these, nine cases (50%) were related to robotic instrument malfunction, four cases (22.2%) involved arm failure, three cases (16.7%) were associated with console failure, and two cases (11.1%) were attributed to optic system dysfunction. Two out of 18 cases (11.1%) were nonrecoverable faults, and one case (0.2%) required conversion to traditional laparoscopy. Chen et al.[50] reported a similar overall rate (3.5%) of robotic device failure in their review of 400 urologic cases at a single institution; their study cited robotic arm

failures to be the most frequent (78.6%) cause of device malfunction.

Kaushik et al.[51] conducted an international survey of 176 urologists performing RARP over a 5-year period; rates of robotic mechanical failures and subsequent management were explored. In total, 100 (56.8%) surgeons reported experiencing a nonrecoverable fault. These events were further stratified to time period they occurred during the procedure. Eighty mechanical failures were cited prior to the start of the procedure; as a result, 46 (57.5%) cases were resecheduled, while 15 (18.8%) and 12 (15%) cases were instead performed in open and laparoscopic fashion, respectively. Sixty-three cases of mechanical failure were reported prior to beginning the urethrovesical anastomosis, and a majority of these procedures (26 cases; 41.2%) were converted to open radical prostatectomy, while 20 (31.7%) cases were converted to conventional laparoscopic prostatectomy. Thirty-two mechanical failures were reported prior to completion of the urethrovesical anastomosis and were completed in conventional laparoscopic fashion in a majority of the cases (62.5%); completion of the urethrovesical anastomosis via laparoscopic means was significantly associated with possessing fellowship training. In general, robotic failure was significantly associated with higher volume surgeons, and the rates of system malfunction were not significantly different between fellowship-trained and nonfellowship-trained urologists. Robotic arm malfunction was reported to represent the most frequent (38%) type of robotic failure. Interestingly, only 68.8% of surveyed urologists reported discussing potential robotic system failures as part of their preoperative patient counseling. Limitations to this study involve its survey format and associated inherent recall bias. It represents a retrospective collection of malfunction events; however, it does not further elucidate the incidence of robotic malfunction, since an absolute number of total cases was not recorded.

Kim et al.[52] reported on a multi-departmental, single institution analysis involving 1797 robotic surgeries; the urology (779 cases; 43.4%) and general surgery (855; 47.6%) departments contributed to the majority of performed procedures. A total of 43 (2.4%) robotic failures were identified involving 24 cases (1.3%) related to mechanical or system error and 19 cases (1.1%) linked to instrument failure. Three cases (0.17%) required conversion to open or laparoscopic surgery.

Nayyar and Gupta[53] performed a retrospective single institution analysis of 340 consecutive robotic urologic surgeries and reported 37 (10.9%) robotic failures. A majority of failures were attributed to robotic instrument malfunction (23/37 failures). Overall, 28/37 (76%) incidents were able to be rectified intraoperatively, leading to successful completion of the robotic-assisted cases. Two cases (0.6%) required conversion. No patient injuries were reported as a result of robotic device failure.

Several studies have explored robotic system failure specifically in RARP. Lavery et al.[54] performed a multi-institutional survey of 11 high-volume centers assessing the frequency of critical (nonrecoverable) robotic malfunction during RARP. During the study time period, 8240 total cases were performed, and 34 (0.4%) nonrecoverable faults were reported. Of these 34 critical failures, 24 cases were aborted and rescheduled, eight were converted to the traditional open approach, and two were completed via laparoscopic technique. The optics (34%) and robotic arm (34%) components were the most frequent culprits involved in robotic system failure. Zorn et al.[55] reviewed a total of 725 RARPs performed at a single institution by two urologists. Four cases (0.5%) of robotic system failure were identified, and all incidents occurred prior to patients' arrival into the operating theater. Optical system malfunction (three cases) and power system failure (one case) were responsible for the dysfunction. All four cases were canceled and rescheduled. Borden et al.[56] (2007) found an overall robotic device failure rate of 2.6% (9/350 cases), with three of these cases requiring conversion to open/laparoscopic procedures.

Consequently, the incidence of robotic device failure is variable in the literature, ranging from as low as 0.4% to as high as 10.9%. The variability between studies may be secondary to different degrees of surgeon learning curves, single- versus multi-institution centers, and the specific generation of robotic model studied. The rates of direct patient harm resulting from robotic system failure remain low. As many of robotic system faults can be detected preoperatively, it is critically important to routinely conduct preoperative safety checks prior to the patient's arrival into the operating room to ensure that all robotic parts are fully functional. Intraoperative management of robotic system failure is performed by first identifying the culprit at fault (e.g., robotic instrument malfunction, robotic arm failure, console failure, optical system malfunction) and determining whether the fault is recoverable or nonrecoverable. Recoverable instrument malfunction may simply require replacement of the instrument to remedy the problem. Often robotic arm collisions or unexpected, quick arm movements may cause recoverable fault errors and can be rectified by clutching the robotic arms and resetting them into a more optimal position. Error codes should be noted in order to report to da Vinci technical support. In cases of nonrecoverable faults that do not resolve with a system restart, the da Vinci Surgical Technical Assistance Team can be contacted to attempt resolution. If unsuccessful, the robotic instruments should be withdrawn, and the robotic arms and patient-side cart should be undocked in preparation for laparoscopic or open surgery conversion. Thus, although the incidence of robotic platform malfunction is low, it is critically important to discuss this possibility with patients, as this has resulting consequences on their course of surgery.

Conclusions

With the undeniable technologic advancements in the minimally invasive field, it is critical for surgeons to keep pace with and advantageously incorporate them into their surgical tool boxes. The key to avoiding the complications associated with robotic surgery is to understand the technology and its pitfalls as well as to continue employing effective core surgical techniques and principles.

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Chapter 31 Questions

1. Which one of the following factors precludes a patient from undergoing transperitoneal robotic surgery?
   a. Age
   b. BMI
   c. Previous retroperitoneal procedure
   d. Uncorrectable coagulopathy
   e. None of the above

2. The advantages of robotic surgery over laparoscopy does not include which one of the following?
   a. Magnified, stereoscopic three-dimensional view
   b. 7 degrees of instrument freedom
   c. Lack of fulcrum effect
   d. Decreased surgeon ergonomics
   e. Increased surgeon ergonomics

3. Which one of the following is not a potential physiologic effect of pneumoperitoneum?
   a. Tachycardia
   b. Increased functional reserve capacity
   c. Decreased urine output
   d. Decreased cardiac preload
   e. Increased systemic vascular resistance

4. Which of the following is a proposed protective factor against compression-related neuropathies during robotic surgery?
   a. Longer operative time
   b. Prolonged Trendelenburg position
   c. Higher BMI
   d. Compression of pressure points
   e. Use of shoulder braces

5. According to the Manufacturer and User Facility Device Experience (MAUDE) database, which of the following accounts for the most frequent robotic system failure?
   a. Console failure
   b. Nonrecoverable fault
   c. Recoverable fault
   d. Camera failure
   e. Instrument malfunction

6. What is the American Urologic Association's stance on venous thromboembolism (VTE) prophylaxis in minimally invasive surgery?
   a. Provide pharmacologic prophylaxis to each patient undergoing minimally invasive surgery
   b. Use intermittent pneumatic compression (IPC) in laparoscopic and robotic surgery as well as identify high-risk patients who may benefit from VTE prophylaxis
   c. Continue pharmacologic prophylaxis after discharge
   d. Discourage use of pharmacologic prophylaxis for patients undergoing robotic partial nephrectomy
   e. Provide pharmacologic prophylaxis only to patients undergoing robotic lower urinary tract surgery

7. Which of the following statements is appropriate in counseling a patient on robotic surgery?
   a. "Robotic surgery is much safer and more effective than open surgery"
   b. "There is no chance that your surgery will require a conversion to an open surgery"
   c. "The robotic platform never experiences a nonrecoverable system failure"
   d. "There is a small but not unrealistic chance that conversion to an open procedure may be required during the course of your procedure"
   e. All of the above

8. Which of the following is not a risk factor for corneal abrasion during robotic surgery?
   a. Increased intraocular pressure
   b. Mechanical trauma
   c. Prolonged Trendelenburg position
   d. Corneal dryness
   e. African American race

9. Which one of the following is false regarding postoperative rhabdomyolysis?
   a. This condition is managed by conservative fluid resuscitation
   b. Patients may experience localized pain or may alternatively lack symptoms
   c. Alkalanization of urine is recommended to prevent acute renal failure
   d. A high BMI is a proposed risk factor for development of this complication
   e. None of the above

10. When exchanging a robotic instrument, the bedside assistant feels resistance; what would be an appropriate next step?
    a. Continue to forcefully advance the instrument against resistance
    b. Gently advance the instrument against resistance
    c. Vocalize that there is an impedance to advancing the instrument, and localize the robotic port as well as instrument under direct vision intracorporeally
    d. Blame the nursing staff for handing over a faulty instrument
    e. All of the above

Answers

1. **d.** Specific contraindications to general trans-abdominal urologic robotic surgery are similar to laparoscopic surgery and include extensive previous abdominal/pelvic surgery or radiation, as well as severe medical comorbidities precluding an operation, such as uncorrectable coagulopathy, severe cardiopulmonary disease, or multiorgan failure.
2. **d.** The advantages of robotic surgery over traditional laparoscopy include a superior magnified, stereoscopic three-dimensional view, 7 degrees of freedom, no fulcrum effect, and improved surgeon ergonomics.
3. **b.** With pneumoperitoneum, intraabdominal pressure rises and, as a result, can have various end-organ implications, including an increase in both the heart rate and systemic vascular resistance secondary to

compression of the intraabdominal aorta and carbon dioxide–mediated sympathetic stimulation. Increased intraabdominal pressure places mechanical compression upon the inferior vena cava, causing decreased perfusion to the heart, ultimately resulting in reduction of cardiac output, especially in a hypovolemic hydration state. Pneumoperitoneum causes respiratory changes, including a reduction in functional reserve capacity (FRC), restricted diaphragmatic excursion, and predisposition to atelectasis. A decrease in renal blood flow as well as in renal function is a transient change expected during induction and duration of pneumoperitoneum.

4. **c.** Longer operative times, prolonged Trendelenburg positioning, compression of pressure joints, and use of shoulder braces are all risk factors for compression-associated peripheral neuropathies. Interestingly, a higher BMI is proposed to be a protective factor against compression-related neuropathies.
5. **e.** The MAUDE database provides a vehicle that allows health-care professionals to voluntarily and anonymously report adverse events related to device failures or malfunctions that impact patient safety. Instrument failure is reported to be the most common type of robotic malfunction.
6. **b.** At this time, the American Urologic Association recommends the use of IPC in laparoscopic and robotic surgery as well as identification of high-risk patients who may benefit from VTE prophylaxis.[38]
7. **d.** A thorough informed consent should be performed, informing the patient of possible risks and benefits associated with a specific robotic procedure, as well as clearly conveying the possibility that the operation may involve conversion to a traditional laparoscopic or an open approach.
8. **e.** Several purported risk factors for corneal abrasions include raised intraocular pressure secondary to prolonged, steep head-down position, corneal exposure and dryness, and mechanical trauma; in this study, African American race served to be a protective factor.
9. **a.** Surgically induced rhabdomyolysis is thought to result from prolonged compression of skeletal muscle associated with decreased blood flow, necrosis, possible compartment syndrome, and, ultimately, skeletal muscle breakdown, with subsequent release of myoglobin and creatine phosphokinase (CPK). Patients may experience tenderness at the site of injury, edema, muscle pain, and dark-colored urine, or may alternatively lack symptoms. Acute renal failure may result in 30–40% of patients and is thought to be mediated by reduced glomerular filtration, intratubular heme cast formation with subsequent obstruction, tubular obstruction by precipitated myoglobin, and a direct nephrotoxic effect via ferrihemate. Aggressive fluid hydration is recommended to produce a urine output of 200–300 mL/hour, and alkalanization of urine is recommended to prevent acute renal failure. Compartment syndromes warrant emergent consultation of orthopedic colleagues to perform fasciotomies.
10. **c.** Passage of laparoscopic instruments outside the console surgeon's field of view can potentially result in damage to visceral organs and blood vessels; thus, laparoscopic instruments should be localized in the body under direct vision, and the bedside assistant should recognize and memorize the spatial path of the instrument to the target surgical area for subsequent insertion. The bedside surgeon should vocalize when passage of a laparoscopic instrument is impeded and withdraw and redirect its course under direct vision to avoid injury to surrounding structures.

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32 Complications of Robotic-Assisted Laparoscopic Radical Prostatectomy

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CHAPTER OUTLINE

Preoperative Considerations
Complications of Positioning
Complications of Access
- Port Insertion/Insufflation
- Bowel Injury
- Bladder Injury
- Retroperitoneal Vascular Injury
- Epigastric/Abdominal Wall Vascular Injury

Intraoperative Surgical Complications
Bleeding
Visceral Injury: Bladder, Bowel, and Rectum
Ureteral Injury
Nerve Injury

Early Postoperative Complications
Bleeding
Anastomotic Urine Leak
Lymphocele
Urinary Tract and Wound Infection
Thromboembolic Complications
Port Site Hernia

Late Postoperative Consequences
Incontinence
Impotence
Oncologic Outcomes

Chapter 32 Questions and Answers

KEY POINTS

1. Candidates for robotic-assisted laparoscopic radical prostatectomy (RALRP) must have adequate ventilatory reserve and appropriate body habitus to allow maximal Trendelenburg position during the procedure.
2. The risk of nerve and pressure injuries during RALRP can be reduced by avoidance of stirrups, adequate padding, and shoulder support.
3. Unrecognized bowel injury most commonly occurs due to movement of instruments outside the visual field of the camera.
4. Blind trocar insertion risks injury to the aorta, common iliac arteries, mesentery, bowel, and bladder.
5. Bleeding resulting from incision of the dorsal venous complex can generally be managed by completing the transection, slightly increasing insufflation, and directly suturing the stump.
6. Controlled urine leak from the vesicourethral anastomosis can generally be managed conservatively with catheter drainage, but persistent leak should draw concern for a ureteral injury.
7. Ureteral injury can occur during node dissection, adjacent to the seminal vesical pedicle, but generally occurs during bladder neck transection.
8. Rectal injury can be managed by robotic-assisted laparoscopic repair, except in cases of fecal soiling, large injuries, devitalized rectal wall, or previous radiation. In these cases, colostomy diversion should be considered.

The surgical management of prostate cancer has rapidly evolved over the past decade from a procedure most commonly performed open by a subset of urologists skilled in the approach, to a minimally invasive procedure more accessible to a wide range of well-trained urologists. The proportion of prostate cancer operations performed laparoscopically, with or without robotic-assistance, continues to grow globally. The choice of robotic-assistance is, in many cases, a function of accessibility within a given health-care system, but use of the robot often shortens the learning curve and facilitates a minimally invasive approach among surgeons not comfortable with the laparoscopic, nonassisted, approach.

As a result, robotic-assisted laparoscopic radical prostatectomy (RALRP) became the surgical technique of choice in the treatment of localized prostate cancer with 60% of patients in the United States treated with this technique by 2009,[1] and presumably far more by 2016.

Early evidence showed that RALRP was associated with reduced blood loss, decreased transfusion rates, and lower narcotic requirements postoperatively,[2] but concerns remained regarding catastrophic complications in the hands of inexperienced surgeons, high cost, and a failure to demonstrate improvements in functional recovery following surgery. More recent data have also been promising regarding more durable – and arguably more clinically meaningful – outcomes, such as long-term cancer control, functional recovery, and health-related quality of life. Data suggest that these outcomes are at least equivalent to, and possibly superior to, outcomes after traditional open radical prostatectomy (ORP).[3–5]

It is notable that in the hands of most surgeons experienced with the technique of RALRP, the procedure has become routine. A primary attraction of the procedure is that the approach allows adaptation, in most cases, irrespective of anatomic variation, gland size, or previous surgery. These factors add complexity to the operation, and thus surgeon experience remains a critical determinant of success or failure. While most surgeons carry a high level of comfort with the RALRP procedures, a risk of complications remains, and given the number of procedures performed in the United States, review of potential complications, their management, and strategies for prevention are critically important.

Preoperative Considerations

As with any surgical procedure, determining surgical candidacy is an important element of the preoperative evaluation before considering RALRP. There are general contraindications to surgery that may relate to either general comorbidities precluding anesthesia, or cancer-related risk factors that predict a high likelihood of treatment failure. The oncologic indications for surgery are beyond the scope of this chapter, but given the wide variation in selection criteria, the ultimate decision to offer RALRP depends largely upon the treatment biases and strategy of the managing surgeon and institution. In general, candidates for a laparoscopic approach include patients at relatively low risk for adverse cardiopulmonary and anesthetic complications associated with the surgical procedure. In some circumstances, anesthetic considerations related to pulmonary disease and the ability or inability to compensate for the hemodynamic, cardiovascular, and metabolic changes associated with the various physiologic particularities that occur during laparoscopy might serve as relative contraindications. The steep Trendelenburg positioning undertaken during RALRP could further increase respiratory stress, and patients with underlying respiratory disease, morbid obesity, or anatomic abnormalities may not tolerate this surgical approach well.

A prior history of intraabdominal and pelvic surgical procedures, disease processes, or previous radiation therapy may also influence the appropriateness of a laparoscopic robotic-assisted approach. Although no clear guidelines are available, the presence of intraabdominal or pelvic adhesions may certainly make exposure and creation of a working space more difficult, and the decision to proceed laparoscopically is based upon surgeon experience and comfort level.

In general, we have not found previous intraabdominal surgery to be a contraindication to RALRP, but surgical time is clearly extended due to the need for laparoscopic lysis of adhesions to create working space. In these patients, options such as extraperitoneal approach RALRP could also be considered, but such an approach requires experience with the technique, and development of the extraperitoneal space may be limited by incisional adhesions as well. The need for conversion to an open surgical approach is a realistic possibility in these patients, and as such, preoperative arrangement for availability of a surgeon experienced with ORP is advisable. Likewise, in cases of complicated previous intraabdominal surgery or infection (i.e., perforated diverticulitis, trauma, abscess, etc.) one might consider advising ORP rather than attempting RALRP, depending upon the experience level of the surgeon.

Previous pelvic surgeries, including bladder surgery, simple prostatectomy, lower abdominal mesh placement, renal transplant, or vascular grafting, may create challenging extraperitoneal adhesions, limiting the approach to the prostate during RALRP. In our experience, mesh is the most commonly encountered obstacle, and a careful history with review of previous operative reports may aid in surgical planning. When mesh placement is limited to the deep inguinal ring or anterior abdominal wall, cautery along the mesh surface generally allows the bladder to drop easily away. Caution must be exerted not to stray laterally to the mesh, or through the mesh into the anterior abdominal wall, to avoid vascular injury. In this regard, dealing with mesh placed extraperitoneally over the inguinal ring is better dealt with by RALRP than ORP, as mesh is more likely to be encountered and traversed during the open or extraperitoneal approach while attempting to access the space of Retzius. Most troublesome is the scenario in which mesh extends over the iliac brim and vessels. In these cases, we generally do not attempt pelvic node dissection due to risk of vascular injury, and the bladder is released laterally only to the root of the superior pedicle. In general, mesh does not extend beyond the distal iliac vessels in these cases, and adequate bladder mobility can be achieved through simple release from the mesh.

In cases of previous bladder surgery, perivesical adhesions can be more substantial, and bladder injury often occurs during mobilization. Intravesical instillation of dilute methylene blue can allow recognition of small injuries that can easily be repaired. In patients with previous renal transplant or pelvic vascular graft, RALRP may be contraindicated, depending upon the experience level of the operating surgeon. Liberal use of cautery during bladder mobilization should be avoided if RALRP is undertaken, as inadvertent injury of blood vessels or transplant ureter can have dire consequences. We have previously performed RALRP in men with previous renal transplant, and preoperative assessment of anatomy is essential. In these patients, the allograft is generally seated well above the bladder, and the ureter enters the dome of the bladder. Avoidance of this

region is feasible through cautious entry into the retropubic space along the anterior abdominal wall.

Salvage laparoscopic robotic-assisted prostatectomy following radiation therapy may be particularly challenging. In complex cases characterized by anticipated fibrosis, adhesions, and altered anatomic features, the decision to proceed with a laparoscopic approach should be based on risk assessment and the surgeon's experience. In general, we have found salvage prostatectomy to be simpler through a robotic-assisted approach rather than open.

Morbid obesity itself does not pose a contraindication to RALRP, but particular preoperative considerations should be taken. Specifically, the surgeon should be aware that full Trendelenburg positioning might not be possible in these patients, due to difficulty with ventilation in the setting of abdominal insufflation. Further, port placement may need to be displaced somewhat inferiorly, often below the umbilicus, in order to allow for the robotic arms to gain access to the most caudad portions of the pelvis.

As in open radical prostatectomy, patients undergoing laparoscopic robotic-assisted prostatectomy should receive appropriate perioperative antibiotic and deep vein thrombosis prophylaxis. We have utilized both compression stockings and preoperative administration of prophylactic dose subcutaneous heparin as a routine in all men undergoing RALRP.

COMPLICATIONS OF POSITIONING

Complications of positioning are discussed in detail in Chapters 9 and 31. The da Vinci Si system (Intuitive Surgical, Sunnyvale, CA) has typically been employed with the patient in a modified low lithotomy position with steep Trendelenburg decline. The robot is generally positioned between the legs allowing the operating component of the robotic system to come into close proximity to the patient, with the operating arms and camera oriented toward pelvic targets, including the prostate, bladder, seminal vesicles, urethra, and genitourinary diaphragm. Alternatively, a side-docking approach, in which the robot is positioned at an angle lateral to the pelvis, allows adequate exposure and enables versatility of positioning the patient in a supine or lithotomy position. Since adaptation of the Xi system, we have routinely placed the patient supine in steep Trendelenburg position. Such an approach minimizes the risk of lower extremity compartment syndromes and perineal nerve injury related to the stirrups.

Close attention to positioning is important to prevent pressure or traction-associated nerve injuries. Accordingly, all pressure points should be padded adequately, and the surgical team, including the anesthesiologist and nursing staff, should ensure that areas of potential injury are addressed before sterile skin preparation and draping. In the SI positioning, the weight of the patient's legs should be transmitted through the heel and foot, minimal pressure should be present on the lateral aspect of the calves and thighs, the extension of the hip and thigh should be anatomic to minimize the risk of femoral nerve injury, and the lower back should be contoured with lumbar support if necessary. If the arms are positioned by the patient's side, the wrists and elbows should be well padded, and care should be taken to protect the patient's hands and fingers from injury secondary to positioning of the table, robotic equipment, or the assisting surgical team. When the patient's arms are not tucked, a natural anatomic position of the arm and shoulder should be achieved to prevent brachial plexus injury. Adequate shoulder support, without compression of the shoulders, is essential to avoid brachial plexus stretch injury.

Once the patient has been correctly positioned, he should be secured to the surgical table to prevent shifting during the surgical procedure. We generally observe the patient in Trendelenburg position prior to draping to ensure no slipping occurs. This goal can be achieved relatively easily by using padded straps across the patient's chest. Additionally, the use of a high-density padding with a high coefficient of friction, such as the Pink Pad (Xodus Medical, Inc.),[6] helps prevent patient slippage while in steep Trendelenburg and also protects against pressure ulcers and nerve injury. Prior to initiating the procedure, the patient's airway pressure, facial swelling, and body habitus should be carefully observed. Inability to tolerate the position, prior to insufflation, may indicate limited ventilatory reserve, extreme truncal weight impinging upon the diaphragm, or poor venous return from the upper body. In these rare cases, the patient may be a poor candidate for robotic prostatectomy and one could consider aborting the procedure. Additional effects of Trendelenburg procedure can be reviewed in Chapters 9 and 31.

In positioning the operating element of the robotic system, care must be taken to ensure that unintentional contact between the robot and the patient does not occur. The only contact between the robot and the patient occurs through the working ports, and at no time should any other moving or static element of the robot place pressure on the patient's core or extremities. The most common area of potential contact is between the working elements (arms) and the patient's thighs. This contact can be avoided by pivoting the arms of the robot up and away from the patient when the robotic arms are attached to the working ports. Of note, these complications may be less common with use of the da Vinci Xi system due to the fact that the patient is positioned in the supine rather than low lithotomy position, but in that case injury to the feet and lower extremities can occur as the robot is pulled in or out of the field.

One practical concern that may go unrecognized but is potentially serious is the placement of equipment (cables, light source, camera, suction tubing) in the vicinity of the patient's face and the endotracheal tube. Care should be taken when considering placement of these laparoscopic accessories, and if at all avoidable, they should be routed away from the area of the patient's head. In laparoscopic robotic-assisted prostatectomy, however, these accessories are often placed in that area out of necessity. In these cases, a protective foam barrier may be placed over the patient's face after the endotracheal tube has been secured. This measure may prevent facial injuries such as corneal abrasion and may also reduce the risk of unintentional dislodgment of the endotracheal tube during the surgical procedure. Similarly, cords running along the floor should be neatly coiled and protected to avoid inadvertent pulling or disconnection from the robot or endoscopic tower. Such events during the course of surgery can result in loss of vision or failure of the robot.

Critical system failures, although uncommon, may occur, requiring abortion of the robotic-assisted approach and conversion to either a straight laparoscopic procedure or open prostatectomy. A recent survey of 176 urologists who perform RALRP reported that 57% of respondents had ever experienced "irrecoverable intraoperative malfunction" of the da Vinci robotic system either before or during a case. In some cases, system errors prevented initiation of the surgical procedure using a robotic approach (58% of these cases were rescheduled, 19% were performed open, and 15% were performed laparoscopically). Other times, these system errors occurred intraoperatively and required conversion to open or pure laparoscopy. Overall, fellowship trained urologists were statistically more likely to convert to a pure laparoscopic approach versus an open approach.[7] Although information on estimates of system failure is limited, the impact of this system-specific complication on patient and cancer-related health outcomes has not been measured to date.

COMPLICATIONS OF ACCESS

Port Insertion/Insufflation

Complications of laparoscopic access are additionally reviewed in Chapters 30 and 31. Laparoscopic robotic-assisted radical prostatectomy may be performed through either a transperitoneal or an extraperitoneal approach. Although the transperitoneal approach is more commonly used, some surgeons prefer the extraperitoneal approach because the peritoneal contents can be avoided. In this case, the working space is generally smaller, and cranial access to high lymph nodes may be limited. Both approaches have advantages and disadvantages and present different potential challenges in access. Regardless of which approach is used, initial access to the peritoneal or perivesical space is typically achieved through a small periumbilical or infraumbilical skin incision.

The transperitoneal approach uses intraperitoneal access with secondary entry to the retropubic, extravesical space through eventual incision of the parietal peritoneum. Access to the peritoneal cavity may be gained by abdominal insufflation through a Veress needle followed by blind insertion of the initial camera port or use of a Hasson technique for direct cut-down and visualization of the peritoneal incision. While we have generally preferred a Hasson technique of insertion in all cases, this technique is strongly indicated in cases of previous intraabdominal surgery from which bowel adhesions may be present, when direct visualization is preferable. Following standard laparoscopic principles, confirmation of an intraperitoneal position is necessary before insufflation. In obese patients, when using the Hasson technique, the trocar tip can easily be displaced to the preperitoneal space. Abnormally high initial intraabdominal pressures indicate probable malpositioning, and insufflation should not be initiated in this setting. Repositioning, removal, and replacement of the device are options to establish correct placement before insufflating the abdomen. Nonvisualized passage of the Veress needle and the initial trocar following insufflation is associated with potential injury to gastrointestinal and vascular structures. If an injury is suspected after placement of the Veress needle, insufflation should be delayed and the needle should be carefully removed in the trajectory of entry to avoid converting a penetrating injury to a potentially more severe laceration. In these cases, or in cases of previous midline incision, a Hasson technique for trocar insertion can be carried out laterally to visualize the midline adhesion and perform laparoscopic lysis of adhesion, or inspection of suspected injury, prior to placing midline trocars. Once safe access has been established in a different location, the area of initial entry and potential injury should be examined closely. In cases of small penetrating injuries due to needle insertion, usually no additional management is required for bowel or bladder entry.[8] Injuries associated with trocars are generally more severe and often require laparoscopic or open repair. The surgeon must use his or her discretion regarding the need for repair or conversion to an open procedure.

The extraperitoneal approach requires port placement slightly lower than in the transperitoneal approach but in the same configuration. Potential benefits of the approach include reduced anesthetic problems associated with increased intraperitoneal pressures, avoidance of the peritoneal contents and all associated intraoperative and postoperative consequences (ileus), and decreased need to retract the bowels during the surgical procedure. Additionally, the risk of trocar injury to the bowel is reduced, but bladder injury or vascular injury due to the reduced size of working space remains a potential problem. The working space is smaller, and care must be taken in developing the extraperitoneal space before port placement, particularly in the cranial and lateral areas where the robot working ports are placed. A balloon dilator is used to develop the prevesical space bluntly and may result in laceration or avulsion of small pelvic vessels. This is generally not problematic, except in the case of previous pelvic surgery or fibrosis secondary to previous pelvic infection. In these cases, fused tissue planes can result in adherence of the peritoneum to pelvic vessels, resulting in more significant vascular injury on insufflation. In cases of suboptimal development of the prevesical space, the working space can be limited, resulting in a relatively reduced ability to manipulate the working elements and translating to more difficult surgical dissection. Initial port placement to gain proper access to the space is essential because improper placement may result in occult or obvious intraperitoneal entry and bothersome intraperitoneal leak throughout the procedure. In cases of intraperitoneal insufflation, bulging of the peritoneum further restricts the working space. In the event of an intraperitoneal communication, a 5-mm port can be placed into the peritoneal space for decompression. Conversion to an intraperitoneal approach should be done if a large intraperitoneal CO_2 leak occurs.

Subcutaneous emphysema may develop during the course of the procedure, either due to trocar placement or migration to the preperitoneal space, a very prolonged procedure, or a CO_2 leak around the trocar site. Scrotal emphysema is common, and in prolonged cases, emphysema may migrate up the abdominal wall and involve the subcutaneous tissues of the neck and face. This problem is directly related to the extent of CO_2 leakage into the extraperitoneal space, which may be exacerbated by prolonged surgical time, use of high insufflation pressures, and insufflant leak around the fascial opening. Palpable crepitus is the principal clinical sign. When subcutaneous emphysema is

associated with high CO_2 blood levels, delayed extubation may be required to allow the partial pressures of CO_2 and of oxygen to normalize. Maintaining intraperitoneal pressures of ≤15 mm Hg assists in minimizing this complication.

Many devices, including the Kii Balloon Blunt Tip System by Applied Medical, can reduce the chances of troublesome air leak around the trocar throughout the case, given the relatively large fascial opening required during the Hasson approach. This device works by trapping the fascial opening in an airtight manner between an external mobile gel cone and an internal balloon posterior to the peritoneal opening.[9] Alternatively, a pre-placed "purse-string" fascial stitch can be used to tighten the point of fascial entry around the trocar, reducing the tendency of air leak. We have found the latter maneuver to work poorly and have routinely utilized the balloon port, both with the Si and Xi systems.

Although uncommon, the risks of gas embolism and resulting cardiopulmonary collapse are elevated during laparoscopy. Embolism is less common when one uses CO_2 compared with other insufflants, given the dissolvability of CO_2 in blood.[10] In cases of unrecognized intravascular entry, injury, and insufflation, a CO_2 embolus may precipitate rapidly and may result in catastrophic consequences such as acute cardiovascular collapse. This is the most common cause of a gas embolism in the setting of CO_2 insufflant. Classic signs include an abrupt increase in end-tidal CO_2 accompanied by a sudden decline in oxygen saturation and a subsequent decrease in end-tidal CO_2.[10] Such cases should be managed on an emergency basis with immediate cessation of insufflation and repositioning of the patient in the left lateral decubitus position to minimize right ventricular outflow. The patient should then be ventilated with 100% oxygen, and in extreme circumstances, aspiration of the air embolism may be required.

Bowel Injury

Perforation of the small bowel or large intestine is the most common injury associated with initial blind trocar placement and usually relates to bowel adhesions or a downward angulation on trocar insertion. Prompt recognition of the injury is essential, and the decision regarding management is largely based upon surgeon experience and the severity of the injury. In cases of injury to bowel fixed by adhesion, release of the adhesion is essential to properly evaluate and, if needed, repair the injury. Additionally, tethering of the bowel can stretch and expand the diameter of the injury. Repair can be performed laparoscopically, with or without robotic assistance, or through an open converted approach, depending upon the comfort level of the surgeon. If converting to open, completion of the prostatectomy could be considered, with repair of the bowel via the specimen extraction site if intraoperative fecal spillage is not noted. In that case, isolation of the bowel with stay sutures until the time of repair is prudent. General principles of bowel repair are employed. Injury to intraperitoneal structures is less common with an extraperitoneal approach because the peritoneal contents are avoided. Nonetheless, small bowel and large intestine injuries are possible secondary to unintentional peritoneal entry during establishment of access, thermal injuries, or inadvertent traction to fixed bowel segments within the peritoneal cavity. Delayed recognition of a bowel injury can be catastrophic. Patients will often present with peritonitis, sepsis, and intraabdominal abscess within 2–7 days following surgery.

Bladder Injury

Significant bladder injuries may also occur during the establishment of access. Bladder injury by trocar is usually quite evident and is easily managed by direct repair. Suspected needle bladder injuries can be detected with intravesical instillation of dilute methylene blue. Small penetrating injuries associated with narrow-gauge needles can be managed conservatively.[8] Urinary decompression with a Foley catheter reduces the risk of injury and should be routine practice before laparoscopic access is gained.

Retroperitoneal Vascular Injury

Major vascular injuries are rare and have been reported in recent meta-analyses to occur in 0.044% and 0.03% of laparoscopic cases using the Veress needle and Hasson approaches, respectively.[11,12] The aorta and common iliac vessels are the most commonly injured vascular structures, as they lie directly beneath the periumbilical trocar insertion site. Injury to these major structures can result in catastrophic bleeding, but such injuries can usually be salvaged through prompt intervention. Mesenteric vessels may also be injured, resulting in mesenteric hematoma followed by possible vascular compromise and bowel ischemia. Clinical signs of significant bleeding are hypotension followed by compensatory tachycardia. After trocar entry into a major vessel, injury is often readily apparent on removal of the obturator or pull back of the trocar and insertion of the camera. If the trocar has not been withdrawn or manipulated, a blunt obturator should be replaced through the lumen and the trocar should be left in place while preparations are made for open conversion and repair. While usually evident, during some cases of tangential vascular injury, blood may dissect beneath the mesentery and bleeding may not be apparent, even on intraperitoneal inspection. An emergency laparotomy should proceed rapidly with vascular control and repair.

Epigastric/Abdominal Wall Vascular Injury

Trocar insertion commonly can also result in injury to the inferior epigastric artery and veins, or their tributaries. Injury is recognized either at the time of insertion, based upon visual inspection, or at the time of port removal. In general, the risk of injury can be minimized when the vessels are directly visualized and ports are placed >6 cm from the midline,[10] and lateral ports are placed under direct vision. In thin patients, use of the laparoscope light to transilluminate the abdominal wall can aid in selecting an appropriate site for port insertion. Use of a spinal needle to map the trans-abdominal course of the trocar may also help prevent injury to the inferior epigastric vasculature.

Recognized inferior epigastric injuries should be managed promptly either laparoscopically or with a cut-down technique. When laparoscopic ligation or electrocautery is possible, additional skin incisions or port placements may be avoided. In some instances, the location of the injury may prevent adequate control without additional port placement. These cases may be managed effectively with additional port placement and subsequent internal ligation. When access to the site of bleeding is difficult, an externally

placed (on the skin level) hemostatic occluding figure-of-eight stitch can be placed in the quadrant of identified bleeding to provide occlusion and control. Endoscopic suturing devices are very useful in this application because they allow full-thickness transabdominal suturing, and this has been our preferred management of abdominal wall bleeding when recognized intraoperatively. Unrecognized or inadequately managed hemorrhage from the inferior epigastric vessels may progress to a significant rectus sheath hematoma resulting in clinically significant pain, acute blood loss, anemia, and possible hemorrhagic shock.

Intraoperative Surgical Complications

Specific intraoperative complications arising during RALRP, unrelated to port insertion and insufflation, are similar to those occurring during ORP, but their cause and management may be distinct, owing to the surgical technique. Complications of ORP are reviewed in detail in Chapter 42, and there may be great overlap with this chapter as they are by the same author. Complications of pelvic lymphadenectomy are detailed in Chapter 40 and will not be covered in this chapter.

BLEEDING

A major attribute of RALRP as compared to ORP is the relatively small amount of bleeding encountered during the procedure. In general, while bleeding can occur at any point during the procedure, the severity of bleeding is relatively minimal as compared to with ORP, thus improving intraoperative vision, and improving the ability to control small bleeding sites through enhanced vision. The hemorrhagic advantage of RALRP over ORP is underscored by the differential blood loss between the two approaches: A recent prospective study of 2506 patients found an average blood loss of 185 mL versus 683 mL for RALRP and ORP, respectively.[13] Another study which had similarly significant surgical blood loss differences (207 mL vs 852 mL) also showed that the RALRP group had a reduced incidence of perioperative transfusion rates as compared to the ORP group (4.3% vs 30.3%) and that this likely contributed to a shorter hospital stay (1.8 d vs 2.9 d).[14] It is important to remember that this is surgeon-dependent, and the high rate of transfusion reported in the latter study is extremely high for surgeons of experience performing ORP.

Sources of bleeding are the same as those described for the open procedure: the dorsal venous complex and Santorini's complex overlying the anterior and lateral surfaces of the prostate and bladder, the inferior vesicle and proximal prostatic vascular pedicles, the neurovascular bundles coursing posterolateral to the prostate, the apical prostatic vessels, and the bladder neck. One reason for reduced bleeding during RALRP is the pneumatic pressure provided by insufflation of the working space. Under conventional insufflation pressures, small vessels surrounding the prostate, and in many cases even the dorsal venous complex, can be cut without major bleeding. This is an important recognition, as a common cause of delayed bleeding is de-sufflation with ensuing bleeding from uncontrolled small vessels controlled by pneumatic pressure during the procedure. As such, following completion of the procedure, inspection of the field under reduced insufflation pressure of 5–8 mm Hg can be a valuable tool in preventing delayed bleeding.

Division of the dorsal venous complex can be performed early in the procedure or late. If performed prior to bladder neck division and prostate mobilization, the dorsal vein should be controlled directly with a figure-of-eight suture of 2-0 Vicryl or, in some cases, an Endo GIA stapler. Adequate suture ligature of the dorsal vein requires sufficient division of the adjacent endopelvic fascia to allow central bunching of the complex within the suture. In cases of retraction of the dorsal vein following division, direct oversewing of the vein stump is generally feasible. We have generally divided the dorsal vein complex after division of the bladder neck and complete mobilization of the entire gland. In doing so, the complex can be sharply divided without prior suture ligature, allowing maximal anterior surgical margins while avoiding excessive dissection or suture placement in the periurethral space. During division of the uncontrolled dorsal vein, bleeding can be encountered, particularly when only partially transected. Bleeding can be minimized by avoiding stretch or traction on the vein, avoiding excessive suction or reduction of insufflation pressure, and, on occasion when needed, actually transiently increasing insufflation pressure to 20 mm Hg. The latter maneuver is generally safe, but one must be cautious if large open venous sinuses are visible, due to the rare occurrence of air embolus. Following division, we generally oversew the edge of the dorsal vein complex in a running fashion, incorporating only the edges of the vein complex to avoid deep suture placement. The complex is then suspended to the pubic symphysis by incorporating the posterior pubic periosteum into the running closure stitch. In general, dorsal vein complex bleeding should not be excessive in RALRP, regardless of the technique of division utilized.

In general, use of sharp dissection and nonthermal mobilization of the periprostatic layers, desirable for minimizing trauma to the adjacent neural structures, increases the risk of bleeding both in the field and postoperatively. High anterior release of the lateral prostatic fascia requires mobilization of the fascia from the lateral surface of the prostate. As the fascia is often intimately adherent to the periprostatic venous complex, small venotomies are frequently encountered. We have generally utilized an approach of retrograde neurovascular bundle mobilization, adapted from our open technique (Fig. 42.3), by releasing the lateral fascia of the prostate and mobilizing it sharply and bluntly from the posterolateral prostate, to the level of Denonvillier's fascia, thus laterally displacing the nerve bundle (Fig. 32.1). Denonvillier's fascia is then incised, entering the perirectal space (Fig. 32.2), and a cottonoid sponge is packed into the defect to tamponade venous oozing from the mobilized nerve bundle and lateral fascia (Fig. 32.3). After excision of the prostate, bleeding encountered along the neurovascular bundles or lateral prostatic fascia can generally be controlled by reapproximating the overlying fascial layers in a running or interrupted layer of 3-0 Vicryl suture, or by cautious point coagulation with bipolar cautery, as needed.

Division of the bladder neck, particularly the lateral attachments of the bladder to the prostate, when establishing the posterior plane behind the bladder neck can

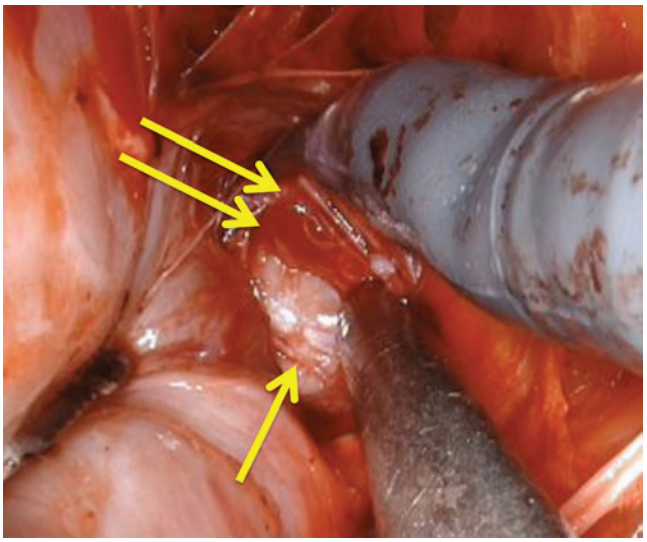


Figure 32.1 Taneja's retrograde technique of neurovascular bundle dissection. Prior to division of the urethra or bladder neck, the endopelvic fascia is incised and the prostate is freed from the sidewall to the level of the perirectal fascia. The lateral fascia is incised and reflected off the posterolateral surface of the prostate. The neurovascular bundle is reflected laterally in an extrafascial fashion (double arrow), exposing Denonvillier's fascia medial to the nerve bundle (single arrow).

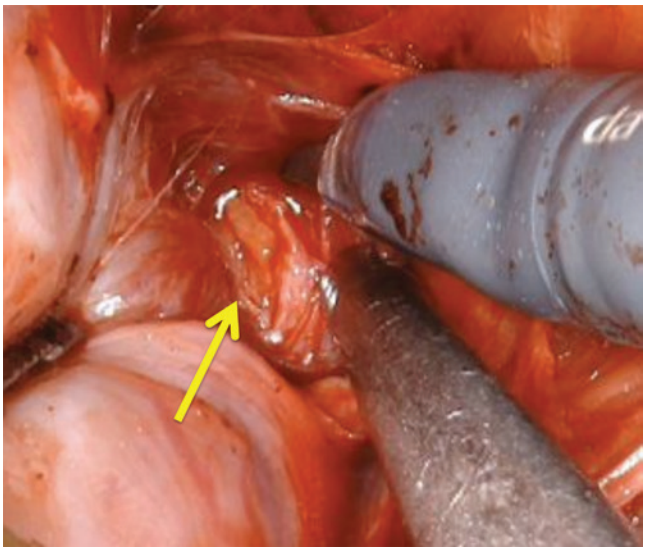


Figure 32.2 Taneja's retrograde technique of neurovascular bundle dissection. Denonvillier's fascia is sharply incised, exposing the perirectal fat in the retroprostatic space (arrow).

result in significant bleeding from the perivesical extension of Santorini's plexus and the arterial branches extending to the bladder neck. Generous use of bipolar cautery or preemptive clip placement can avoid oozing from this location, which may impair vision greatly. Once bleeding from a transected vessel occurs, it often retracts within the partially divided bladder neck. Efforts to control small bleeding points are often fruitless and may be best employed following complete division of the bladder neck and prostate pedicle. Prostatic pedicle bleeding is not unusual, but is generally minimizing by liberal use of clips during

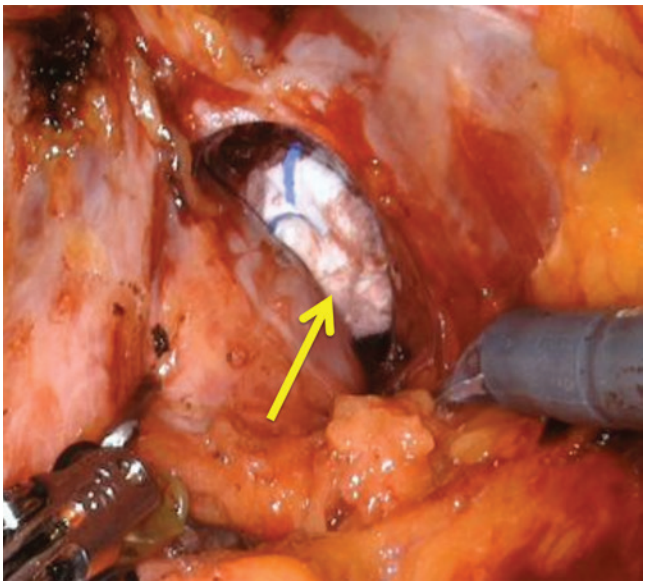


Figure 32.3 Taneja's retrograde technique of neurovascular bundle dissection. A cottonoid sponge is packed into the defect to tamponade any bleeding along the neurovascular bundle, until the prostate is excised.

the division to avoid excessive cautery. Upon division of the pedicle, small venous bleeding often stops as traction on the cut vessel is released. Direct suture ligature of the divided pedicle is preferable to attempts at clipping or cauterizing retracted vessels.

A final point of potential bleeding is the seminal vesical pedicle. Arterial supply of the seminal vesical branches arises from the inferior vesical circulation of the hypogastric artery. As such, retracted vessels can be the cause of intraoperative or delayed postoperative bleeding. Direct control of the pedicle with clips is desirable to avoid transmission of cautery to the neurovascular bundle, but if avulsed and retracted, exposure followed by point coagulation with bipolar cautery can be utilized.

VISCERAL INJURY: BLADDER, BOWEL, AND RECTUM

Visceral injuries during RALRP can include injuries to bowel, bladder, and rectum by a number of variable mechanisms. Early recognition and repair is a critical tenet of management, regardless of the site of injury. Direct injury during dissection or mobilization is often recognized while injuries due to instrumentation out of the visual field, thermal injuries, or traction injuries may go unnoticed and present later at the time of visceral leak or infection.

Bladder injuries commonly arise during mobilization of the bladder. In the transperitoneal approach, division of the urachus and entry into the retropubic space can result in an inadvertent cystotomy. Such injuries are most often encountered in cases of previous pelvic surgery, hernia mesh, or by entry into the incorrect plane, too close to the detrusor muscle. Similar risks of injury to the bladder exist during insufflation of the perivesical space for an extraperitoneal approach prostatectomy. The incidence is <2% during laparoscopic prostatectomy, and this complication

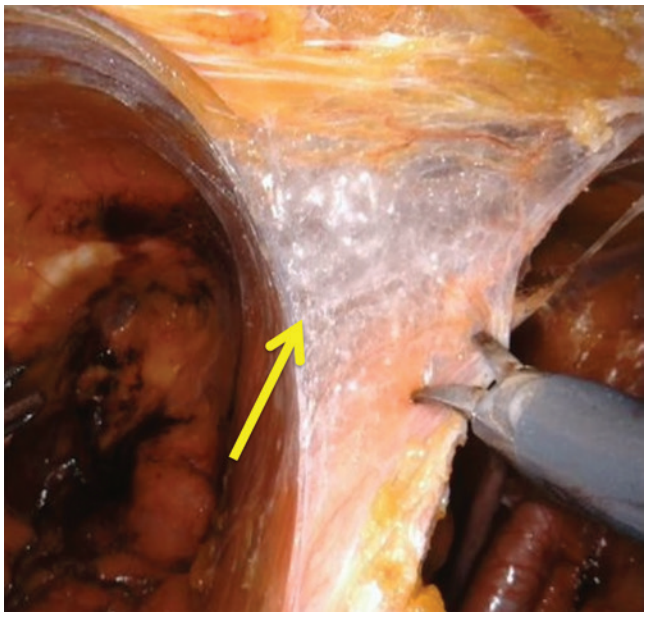


Figure 32.4 In mobilizing the bladder from the anterior abdominal wall, after division of the urachus, an avascular plan is identified between the perivesical fat and the posterior rectus fat, in order to avoid cystotomy and injury to the tributaries of the epigastric vessels. This plane (see arrow) is extended to the level of the pubic symphysis.

can be effectively managed with two-layer closure and bladder decompression.[15] In cases of multiple cystotomies or when the integrity of the anterior bladder has been compromised secondary to misguided surgical dissection, additional repair may be necessary.

Mobilization of the bladder should be carried out in a largely avascular plane, identified upon complete division of the urachus (Fig. 32.4). When traversing this plane to the level of the endopelvic fascia, excessive bleeding may indicate entry into the perivesical space or the posterior rectus fat, adjacent to the epigastric vessels. Early lateral mobilization of the bladder during the pelvic node dissection often defines the appropriate plane, thereby facilitating release of the urachus. In cases of sliding hernia, the bladder wall may extend into the hernia defect. Early recognition of the hernia, followed by reduction of the contents prior to further bladder mobilization, will avoid inadvertent cystotomy.

Bowel injury to the small bowel, colon, or rectum can occur at various points during the surgery. In handling the bowel, blunt retraction, rather than grabbing and pulling, is desirable as the strength for the robotic instruments is often underestimated. Any tether of the bowel due to adhesion or peritoneal attachment can result in a serosal or full thickness injury of the bowel wall. Commonly, injuries may occur when robotic instrumentation is moved while out of the visual field, or by the assistant's instrumentation as it is moved in and out of the visual field. As such, in establishing the pelvic working space, it is critically important to ensure the bowel remains well mobilized and out of the path from assistant port to operative field. Robotic instruments should remain in the field with short, controlled movements, paralleling movement of the camera.

As the sigmoid colon is often adherent to the left pelvic sidewall overlying the pelvic brim, wide release of lateral attachments and medial reflection sufficient to drop the rectosigmoid well below the dome of the bladder are advisable. Small bowel, present in the posterior cul-de-sac of the bladder should be swept out of the pelvis toward the upper abdomen with release of any tethering adhesion. Upon division of the urachus, the bladder serosa layer and urachus can be used to protect the underlying bowel through cranial retraction.

In addition to direct injury, cautery injury is common, and a more difficult to identify, mechanism of injury to the bowel. Arc injuries occur when cautery is transmitted to adjacent structures from a monopolar instrument. Careful inspection of the overlying sheath of the instrument will avoid unexpected transmission of cautery from the shaft, and limit delivery of cautery to the tip of the instrument, where it can be better controlled. When cautery injury does occur, inspection of the tissues will determine the necessity for repair. Blanched tissue with apparent lack of capillary refill is suggestive of devitalized tissue, and one should consider preventive repair, either through imbrication and reinforcement with interrupted seromuscular sutures, or, in the case of severe injury, bowel resection and primary repair. Delayed recognition of thermal injury to the bowel can have catastrophic outcomes, with patients often presenting 3–10 days after surgery with fever, leukocytosis, abscess formation, peritonitis, and/or sepsis.

Rectal injury, which has an incidence of 0.2–1.0% during RALRP, usually occurs during the dissection of the prerectal space or mobilization of the seminal vesicals. It is more common in patients with a history of prior transurethral resection of the prostate, pelvic radiation, or with periprostatic inflammation as in the case of multiple transrectal prostate biopsies or prostatitis.[16] Further, patients with high-grade or locally advanced disease, who require a wider resection of the neurovascular bundles, may be susceptible to rectal injury along the anterior and lateral rectal wall. For this reason, it is advisable to consider mechanical bowel preparation prior to surgery in patients considered to be high risk for rectal injury.

Like other intestinal segments, thermal injury to the rectum can have significant consequences, leading to abscess formation and subsequent rectourethral fistula with or without secondary sepsis. Caution should be exerted to avoid using cautery when mobilizing the seminal vesicals or in elevating the prostate from the anterior rectal wall. Our preference in most cases of low- and intermediate-risk prostate cancer is to traverse between the layers of Denonvillier's fascia when establishing the plane posterior to the prostate. In high-risk patients, excision of both layers of Denonvillier's fascia may be desirable, and in these cases, sharp and blunt dissection under direct vision along the rectal serosa can avoid inadvertent traction injury.

Direct two-layer repair is feasible, by robotic-assisted approach, for most small injuries of the rectum <2 cm in size. In these cases, mucosal closure, followed by an imbricated inversion of the repair with seromuscular sutures, can be utilized. Testing of the air-tight nature of the repair can be performed by instillation of air into the rectum with a piston syringe after filling the pelvis with water. Broad-spectrum antibiotics can be administered for 48 hours, but

in the absence of excessive fecal soiling in the field, prolonged antibiotics are not warranted. Following repair, interposition of tissue between the repair and the vesicourethral anastomosis is desirable. This can be achieved by eversion of the urachus, bladder serosa, or posterior peritoneum through the posterior cul-de-sac and anchoring it to the cut rectourethralis muscle, or using the posterior cul-de-sac peritoneum as a pedicalized flap. Posterior plication or anchoring the detrusor apron to the rectourethralis, can also achieve the goal.

In cases of large or irregular rectal injuries, devitalized rectal wall, previous radiation, or excessive fecal soiling, surgical consultation should be considered along with proximal diversion by loop colostomy at the time of repair. In some cases, rectal resection, with or without primary repair, may be considered. Failure to divert the fecal stream in the setting of complex rectal injury can result in pelvic abscess and sepsis in the event the repair fails to heal.

URETERAL INJURY

Ureteral injury is exceedingly uncommon complication during RALRP, with large series reporting incidences between 0.046% and 0.3%. Authors suggest that ureteral injuries usually occur in the context of difficult anatomic dissection from a history of previous abdominal surgery, prostatitis and pelvic radiation, or during extensive lymphadenectomy. In these patients, it may be useful to preplace ureteral stents for easier ureteral identification and to prevent injury.[17]

Ureteral injury can occur during mobilization of the superior vesical pedicle during pelvic lymph node dissection. It is important to note that the ureter courses medial to the superior pedicle and that injury can be avoided by maintaining node dissection lateral to the pedicle (Fig. 32.5). Inadvertent thermal injury can also occur during seminal vesical dissection. The ureter courses lateral and deep to the tip of the vesical as it enters the trigone. Ureteral injury most commonly occurs, however, at the level of the orifice during bladder neck division. Risk factors include a large median lobe or infiltration of cancer at the bladder neck, requiring wide excision. Similarly, excessive traction following division can tear the posterior bladder neck, bringing the orifices very close to the cut edge.

Ureteral injury management is discussed in detail in Chapters 14 and 43. Extravesical ureteral injury is generally treated by reimplantation of the ureter to the bladder dome. Similarly, transection of the intramural ureter may require reimplant, depending upon the length of ureter retained in the bladder wall. In those cases in which the ureteral orifice or distal intramural ureter is transected, or the cut edge of the bladder neck lies close to the orifice, placement of a double J stent followed by incision of the intramural ureter to mobilize the orifice cranially can provide sufficient distance from the orifice to the cut edge of the bladder neck to allow bladder neck closure or anastomosis.

Failure to recognize ureteral injury at the time of surgery can lead to delayed complications. Urine leak from the injured ureter may manifest as increased drain output in the days following surgery or present at a delayed interval with hydronephrosis, urinoma, infection, or sepsis. In patients with intraperitoneal extravasation of urine, serum creatinine may be elevated. Likewise, inadvertent ligation of the ureteral orifice at the time of vesicourethral anastomosis can result in a transient rise in serum creatinine due to obstruction. As such, any rise in serum creatinine in the early postoperative period should result in consideration of cross-sectional imaging or ultrasound to rule out hydronephrosis and/or urinoma. On rare occasions, ureteral injury may be discovered at a very delayed interval following surgery upon discovery of an atrophic, hydronephrotic kidney.

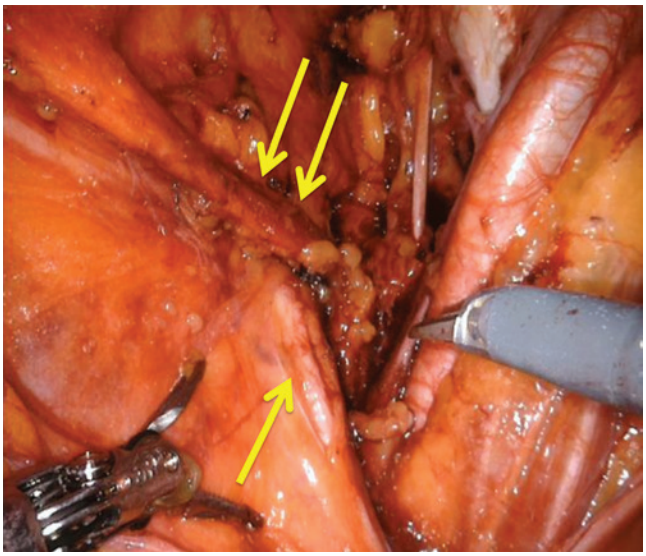


Figure 32.5 In the performance of pelvic lymph node dissection, the ureter (single arrow) courses over the iliac brim and underneath the superior vesical pedicle (double arrow) to enter the retrovesical space. Maintaining dissection lateral to the superior vesical pedicle helps to avoid inadvertent ureteral injury.

NERVE INJURY

Nerve injury may result from patient positioning, inadequate padding, and prolonged surgical duration and occurs in approximately 1.3–1.7% of RALRP cases. Femoral nerve injury is relatively more common during robotic prostatectomy that employs the split-leg bed configuration, while common peroneal nerve injury is associated with RALRP in the dorsal lithotomy position. It is unknown if the incidence of peripheral nerve injury has been decreased in RALRP cases that utilize the da Vinci Xi system, in which the patient is in the supine and Trendelenburg position,[18,19] though side-docking with supine position is generally felt to lower this risk.

The management of nerve injury is discussed in detail in Chapter 9.

Early Postoperative Complications

BLEEDING

Postoperative bleeding following RALRP, while unusual, can be segregated into early postoperative bleeding, occurring

immediately following surgery, or delayed bleeding, which occurs over the first 3–4 days. In general there is overlap between these two scenarios. Profound hypotension, oliguria, or tachycardia in the recovery room, with or without increased sanguinous drain output, should alert the surgeon to the possibility of uncontrolled intraperitoneal bleeding. In these cases, rapid resuscitation is warranted, and early return to the OR should be considered. Most commonly, such bleeding may be from the iliac fossa, due to an uncontrolled vessel within the bed of the lymph node dissection, uncontrolled epigastric bleeding, or unrecognized mesenteric injury. Reoperation, if performed early, could be considered by a robotic-assisted approach, with reinsertion of ports, inspection, clot evacuation, and, when needed, open conversion. In the case of laparoscopic exploration, volume repletion and transfusion is essential as insufflation may reduce venous return, causing hypotension in the hypovolemic state.

More commonly, postoperative bleeding does not result in hemorrhagic shock. A study of 317 RALRP patients reported on five patients who all presented with delayed bleeding in the form of abdominal wall hemorrhage/hematoma that often spread to the lower extremity, all of whom were able to be managed conservatively with blood transfusions. The authors attributed the source of this type of bleeding as being likely from port placement trauma to the inferior epigastric vessels, either from direct laceration of the vessel, or from the extreme tensions caused by the robotic arm movements.[20] Patients with more delayed postoperative bleeding usually demonstrate oliguria, tachycardia, and occasionally hypotension responsive to fluids, over the first 1–3 days postoperatively. Serial hematocrit demonstrates continued decline, even in the face of transfusion. Cross-sectional imaging will usually demonstrate variable amounts of pelvic fluid, as well as subcutaneous and intraperitoneal blood, but is usually not helpful in our experience. Conservative management, with liberal transfusion, fluids, and bed rest, is generally adequate, with bleeding resolving in 3–4 days. Re-exploration in these cases is generally not helpful as a discrete bleeding site within the abdominal wall, or in the pelvis, is usually not identified. In the days that follow, ecchymosis tracking to the scrotum, inguinal crease, and flank may be noted, but should not be alarming as this is dissipation of the previous bleed (Figs. 32.6A–C).

ANASTOMOTIC URINE LEAK

The rate of urethrovesical anastomotic leak (UVAL) varies according to surgical technique and the surgeon's experience, but is generally infrequent. As described in a recent comprehensive evaluation of UVAL in open, laparoscopic, and robotic approaches, the incidence was noted to be highest immediately after surgery (up to 78%) and becomes stable and quite low (8–14%) after about 3 weeks, suggesting no need for continuing the indwelling catheter after that time.[21] In regard specifically to RALRP, one large series showed that the incidence of UVAL based on postoperative cystography at day 7 was 67/442 (13.6%).[22]

Several specific techniques have been proposed to attempt to reduce the incidence of UVAL during RALRP. One study randomized 116 consecutive RALRPs to undergo either single- or double-layer urethrovesical anastomosis. While the single-layer group had statistically higher rates of UVAL at the 1-week cystogram, this did not correlate to long-term urinary leak, bladder neck contractures, or rates of incontinence.[23] A few groups have investigated the role of a barbed plastic "self cinching" suture, the V-Loc,[24] in the completion of the vesicourethral anastomosis. One group found that use of the V-Loc suture led to significantly shorter anastomotic times compared to standard technique (8 min vs 13.5 min).[25] Another group showed no difference in UVAL after the use of this novel suture,[26] and a third group found that the use of the V-Loc led to time reduction, minimal cost savings, and no change in UVAL, bladder neck contracture, or rates of incontinence.[27]

In our experience, clinically significant urethrovesical anastomotic leak is a rare occurrence, largely due to the specific technique utilized in the anastomosis. Given the use of a continuous running suture technique, the likelihood of a gap between sutures or poor coaptation of the mucosa is very low. The ability to accommodate disparities in luminal caliber between the urethra and the bladder neck, without tapering in most cases, adds to the technical advantage over an interrupted suture anastomosis. Suturing is generally carried out from posterior to anterior in a simple continuous technique, with more advance on the bladder neck than the urethra. We utilize two barbed sutures from the 6-o'clock position. Sutures should incorporate a full thickness of urethra and more mucosa than muscle on the bladder neck, in order to create eversion and coaptation.



Figure 32.6 Postoperative bleeding from an abdominal wall vessel can result in significant ecchymosis tracking along the flanks (A and B) and inguinal crease (C). Such bleeding generally is self-remitting and resolves with observation.

Such a technique reduces the risk of leak, but, likewise, greatly reduces the risk of contracture.

If a leak is suspected in the very early postoperative period, it is usually on the basis of increased drain output. Measurement of drainage fluid for creatinine will confirm the presence of a leak. Prolonged catheterization, and drainage, without further intervention, is usually sufficient for management. In cases of very high drain output, and minimal catheter output, slight traction on the catheter could be employed, but the position of the catheter should be confirmed by CT or cystogram to rule out complete disruption. Additionally, high drain output should alert the surgeon to the possibility of ureteral injury. A cystogram can be performed before catheter removal to ensure resolution of the leak, although this is not required in all cases and some authors suggest that after RALRP, as long as the catheter is removed after postoperative day 8, there is little need to perform cystography.[22] In cases characterized by persistent urine leak, a ureteral injury or fistula should be considered as a potential source other than anastomotic leak. In this case cross-sectional urographic phase imaging can be of benefit. In cases of transperitoneal prostatectomy, anastomotic urine leak may contribute to prolonged ileus, which has been reported in approximately 3% of cases.[28] On rare occasions, a urine leak is suspected after catheter removal, on the basis of abdominal distention, ileus, or fever. The presence of intraperitoneal urine can result in an increase in serum creatinine level through reabsorption, but the effect on bowel function is difficult to measure. In approximately 0.4% of cases, urine leak has been seen to extend into the peritoneal cavity resulting in urinary ascites, occasionally requiring CT-guided drainage.[22] While even intraperitoneal leak can resolve with prolonged catherization, drainage of the peritoneal cavity should be considered if ascites is tense, ileus in profound, or secondary infection arises.

LYMPHOCELE

Pelvic lymph node dissection (PLND) during RALRP is thought to lead to increased cancer-specific survival for patients with both node-positive and node-negative disease. The appropriate extent of a lymph node dissection should be directly related to preoperative disease characteristics. Risk of complications such as lymphocele, obturator nerve injury (see above), deep vein thrombosis, and major vascular injury all increase when performing a standard and especially, extended, PLND. Contemporary reviews of PLND during RALRP have assessed that complications attributed to the PLND portion of the procedure range from 0% to 8%. Symptomatic lymphocele is the most common complication after PLND with an incidence of 0–7.9%, but it is thought that minor, subclinical lymphoceles are more common.[29]

The placement of a primary pelvic drain has traditionally been thought to reduce the incidence of symptomatic lymphocele. However, recent studies of patients who underwent robotic PLND show that the incidence of lymphocele does not increase when a pelvic drain is not placed.[30] Many recent studies have also assessed the use of hemostatic agents, ligation devices, and clips in preventing lymphocele creation. One study tested the ability of various energy devices to seal the thoracic duct in pigs and found that bipolar or ultrasonic devices were significantly superior in sealing the large lymphatic channel as compared to monopolar energy devices.[31] Hemostatic agents, although favorable in some studies, have been shown to only add minimal benefits, while adding significant cost. One author suggests that meticulous PLND coupled with the use of bipolar cautery with careful placement of hemostatic clips is sufficient for most experienced surgeons to prevent symptomatic lymphoceles from forming.[32] One novel technique of creating a "peritoneal interposition flap ... by rotating and advancing the peritoneum around the lateral surface of the ipsilateral bladder to the dependent portion of the pelvis and fixing it to the bladder itself" has recently been shown to greatly reduce the incidence of lymphocele formation.[33]

Treatment of lymphocele, discussed in detail in Chapter 40, is dependent on the lymphocele's size and location and whether the lymphocele is infected or symptomatic. Most lymphoceles decrease in size over time, precluding the need for intervention, but those that remain symptomatic usually require more invasive treatment. Percutaneous aspiration often resolves symptomatic lymphoceles without the need for prolonged drainage. In cases of symptomatic reaccumulation, percutaneous drain placement usually alleviates symptoms of pain, serves to drain any infected fluid, and also may decrease the incidence of late DVT. Drains with high output should remain in place until output decreases. However, prolonged high-output lymphoceles may have to be treated with a sclerosing agent such as iodine, alcohol, talc, bleomycin, or tetracycline, and fibrin sealants such as Tisseel. Sclerosis of a large cavity can lead to loculation, so its use should be reserved for high-output, prolonged leaks with a limited, well-drained cavity. In some cases, such as in loculated lymphoceles, another option is to perform a laparoscopic marsupialization of the lymphocele.[32]

URINARY TRACT AND WOUND INFECTION

Although urinary colonization is common following prostatectomy and the associated prolonged catheterization, symptomatic urinary tract infection (UTI) is, in general, not a significant or prevalent problem. According to a recent series of 1000 consecutive RALRP patients, no patients developed a clinically significant urinary tract infection.[34] The risk of perioperative urinary tract infection can be minimized through numerous measures, including the use of appropriate antibiotics preoperatively, early cessation of therapy postoperatively to reduce the risk of selective resistance and *Clostridium difficile* infection, the use of silver-lined antibacterial catheters, and appropriate catheter care during the early postoperative period. Some physicians also prescribe a single or short antibiotic course at the time of catheter removal. In a series of 729 patients who underwent laparoscopic radical prostatectomy, patients who took antibiotics around the time of catheter removal were less likely to develop a UTI (3.1%) as compared to patients who did not take antibiotics (7.3%).[35]

Postoperative wound infection is another uncommon infectious complication of RALRP. In a series of 1000 consecutive RALRP patients, 0.4% developed a wound infection.[34] Contributing factors include suboptimal skin preparation, inadequate sterile surgical technique, prolonged length of operation, suboptimal timing of preoperative antibiotic

administration, incorrect selection of antibiotic coverage, surgical treatment in the setting of active infection or colonization, rectal or bowel injury, and lack of wound irrigation before skin closure.

THROMBOEMBOLIC COMPLICATIONS

The rate of clinically significant venous thromboembolic events (VTEs) has been very low in large RALRP series. For example, in one series of 5951 RALRP patients, the rate of thromboembolic complications was only 0.5%. This found that current smoking, longer operative time, and larger prostate volume were independent risk factors for developing a VTE.[36] Another group found that patients who underwent pelvic lymphadenectomy during RALRP had a significantly higher risk of developing DVT or PE (RR = 7.80 for DVT; RR = 6.29 for PE).[37] Despite the associated risks of pelvic surgery and relative venous stasis secondary to laparoscopic insufflation and increased intracavitary pressure, deep vein thrombosis actually appears to be less common than in the open approach. A study of 94,709 men who underwent either open RP or RALRP found that the comparative odds ratio of developing a VTE was 0.61 (95%, CI 0.45–0.99) for men who underwent RALRP.

There is some controversy regarding the use of periprocedural heparin for the prevention of VTE. The above study of 94,709 men found that patients who received DVT prophylaxis (either mechanical, pharmacologic, or both) were less likely to develop a VTE (OR = 0.67; CI 0.50–0.88).[38] Two studies that compared the use of sequential compression devices (SCDs) alone versus SCDs and heparin found that there was no difference in the rate of VTE between the two groups.[39,40] We have routinely utilized perioperative subcutaneous heparin starting prior to induction, along with SCDs, in our prostatectomy patients, which is discontinued prior to discharge. The management of DVT is discussed in detail in Chapter 4.

PORT SITE HERNIA

Port site hernia is a relatively uncommon complication after laparoscopic surgeries in general, occurring approximately 1% of the time. Most surgeons advocate for port sites >10 mm, located below the arcuate line, to be closed to prevent postoperative small bowel entrapment and herniation during a transperitoneal approach. One study of 498 patients who all underwent RALRP with six port sites (two 12-mm, three 8-mm, and one 5-mm) found that after only closing the 12-mm ports, the incidence of port site hernia was 0.4%.[41]

Bowel herniation from a port site can be prevented by visual inspection of the port entry site and fascia closure before removal of the final camera port. We have pre-placed figure-of-eight closure sutures, at the time of port insertion, to be tied down upon trocar extraction, using an endoscopic stitching device. The Carter-Thomason suturing device is useful for placing simple and figure-of-eight fascial sutures. Many companies have recently come out with newer devices to aid in port site closure. For example, the WECK EFx Endo Fascial Closure System[42] allows for a reproducible closure. One study compared the Carter-Thomason closure device to the WECK EFx system in cadavers. They found that the EFx was superior in terms of time needed to close the defect, safety, and facility, while the Carter-Thomason device was superior in terms of maintaining pneumoperitoneum.[43] A meta-analysis of skin adhesives versus sutures in closure of laparoscopic port site wounds found that skin adhesives were associated with fewer wound infections and less wound dehiscence in addition to higher patient satisfaction.[44]

If bowel does become entrapped in a port site, laparoscopy should be performed with concomitant external manual reduction of the bowel loop. The portion of bowel in question should then be examined, and if it is not viable, bowel resection may be required. When an extraperitoneal approach is used, ports generally do not require fascial closure because intraperitoneal contents are contained within the peritoneum and are therefore not able to herniate through the port sites. The central incision, which is typically extended for retrieval of the specimen, should be closed with care to ensure adequate suture strength and fascial apposition to prevent fascial dehiscence.

Late Postoperative Consequences

Functional complications and oncologic outcomes following laparoscopic robotic-assisted prostatectomy are of particular interest to most surgeons and patients, but they are more difficult to interpret given the variability in reporting methods, the absence of large multicenter datasets, and the poor compliance with long-term follow-up. Nonetheless, emerging data indicate that late postoperative consequences after RALRP such as urinary incontinence and erectile dysfunction are at least equivalent to open RP, if not slightly better. Perhaps intuitively, surgeon-related factors appear to be more important than are patient-related factors. Although complications may or may not vary according to approach (transperitoneal versus extraperitoneal) [45] or other important clinical factors, such as body mass index,[46,47] the experience of the surgeon appears to be a principal determinant of the likelihood of postoperative complications, as RALRP has been consistently shown to have a long learning curve.[48–50]

INCONTINENCE

Most series have reported favorable recovery of urinary continence. Early reports from experienced groups reported 12-month incontinence in 1% of cases[51] whereas others reported return to baseline urinary function in >70% of cases and subjective continence in 90% of cases using more standard assessment methods.[52] More recent series show similar outcomes. One series of 2625 patients reported 78.7% continence rates at 1 year.[53] Another group that recently studied over 4000 patients found that continence rates 1 year after RALRP decreased from 95.1% to 85.6%, 87.8%, and 85.8% in the setting of age ≥70, BMI ≥35, and prostate weight ≥80 g, respectively. Continence at 1 year after salvage RALRP was found to be 51.3%.[54]

When directly compared to the open approach in terms of continence rates at 1 year, the adjusted odds ratio was 1.08 in favor of the RALRP group, although this was not

significant.[53] Another study of one experienced surgeon who performed 1552 consecutive RALRPs or ORPs found that continence scores for RALRP surpassed ORP after the surgeon's 182nd case, suggesting a fairly long learning curve for achieving similar function outcomes.[55]

Many groups have assessed various techniques with the goal of achieving early recovery of urinary continence, including posterior plication, anchoring the detrusor apron of the bladder to the rectourethralis, and dorsal venous complex suspension to the pubic periosteum. One study, for example, describes 252 patients who underwent the total anatomic reconstruction (TAR) technique and showed a continence rate of 98% at 24 weeks post RALRP.[56] Another group compared various reconstruction techniques in a smaller group of patients and concluded that a maximal urethral length preservation (MULP) technique led to statistically significant increases in urinary continence at 1, 3, and 6 months post RALRP.[57]

IMPOTENCE

Recovery of sexual function appears to be more variable and, as reported in open series, more problematic. In one RALRP meta-analysis, 12 and 24 month potency rates ranged from 54% to 90% and from 63% to 94%, respectively. The same study compared potency rates in RALRP versus ORP patients and found an odds ratio of 2.84 favoring RALRP patients for 12-month potency rates.[58] In the aforementioned series of 2625 patients, 70.4% of patients still had some form of erectile dysfunction 12 months following RALRP. This was similar to the ORP group that had a 74.7% erectile dysfunction rate at 12 months.[53]

One group retrospectively studied the potency outcomes of men who underwent RALRP with or without countertraction being placed on the neurovascular bundle. They found a significant increase in potency rates at 6 months when the surgeon used no countertraction, but no differences were observed at 12 months.[59] Another group analyzed erectile function after bilateral nerve-sparing RALRP, which employed an antegrade nerve-sparing approach in 172 patients versus a retrograde approach also in 172 patients. They found that the retrograde approach was associated with increased potency at 3, 6, and 9 months when compared to the antegrade approach, with no change in positive margin rates or continence.[60] As noted earlier, we have routinely employed a technique of retrograde nerve sparing in which little to no traction is placed on the nerve bundle (see Figs. 32.1–32.3).

ONCOLOGIC OUTCOMES

Cancer control following RALRP, as measured by proportion of positive margin, biochemical recurrence, and disease progression, has been shown to be equivalent to, if not better than, ORP. A large contemporary series of 483 consecutive RALRP patients showed biochemical recurrence-free survival, metastasis-free survival, and cancer-specific survival of 73.1%, 97.5%, and 98.8%, respectively at 10 years' follow-up.[61] Another group assessed biochemical recurrence-free survival in 282 RALRP patients and 621 ORP patients across many academic centers and found no difference at 3- or 5-year follow-up periods (HR = 0.98).[62] A third study performed a retrospective analysis of 669 RALRP patients and 357 ORP patients, all of whom had their surgery and pathology analysis performed by the same surgeon and pathologist. Their overall positive margin rates were statistically similar, 18% for RRP and 14% for RALRP. RALRP patients also had lower, although statistically similar, positive margin rates when they analyzed only patients with extraprostatic disease (26.9% vs 35.6%) or men who underwent bilateral nerve-sparing procedures (8% vs 12%).[63] A population-level study used propensity-score matching to compare oncologic outcomes in 13,000 patients using SEER-Medicare data. It found that RALRP patients had statistically lower positive margin rate when compared to the ORP group (13.6% vs 18.3%, HR 0.70; $p < 0.001$), and that RALRP patients had a statistically smaller chance of undergoing additional oncologic-related therapy after surgery (OR = 0.75).[64] In general, given the paucity of randomized comparative data proving superiority of RALRP over ORP, it can be safely assumed that oncologic control is at least equivalent.

Since most positive margins after RALRP have been found at the apical and posterolateral dissection plains, some authors have described techniques that are supposed to decrease positive margin rates at these areas. One author described a technique that employs cranial traction and a 30-degree lens during the apical dissection and found that this decreased the overall positive margin rate by 3%.[65]

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Chapter 32 Questions

1. During the course of robotic-assisted laparoscopic radical prostatectomy, brisk bleeding is noted from division of the dorsal vein. The next step is:
   a. Increase suction to improve vision
   b. Increase insufflation pressure
   c. Attempt to staple the dorsal vein stump
   d. Infrapubic cut down to suture dorsal vein
   e. Open conversion

2. The most common site of major vascular injury during blind trocar insertion is:
   a. Superior vesical pedicle
   b. Vena cava
   c. Aorta/common iliac artery
   d. Hypogastric artery
   e. External iliac vein

3. Unrecognized bowel injury during robotic-assisted laparoscopic radical prostatectomy is most likely to occur due to:
   a. Thermal arc
   b. Excessive traction on the bowel during dissection
   c. Lysis of adhesions
   d. Movement of instrumentation outside the visual field
   e. Trocar injury

4. Prolonged postoperative bleeding resulting in significant ecchymosis of the flanks and inguinal crease most often is the result of bleeding arising from the:
   a. Dorsal vein complex
   b. Iliac vein or tributaries
   c. Superior vesical pedicle
   d. Abdominal wall vessels
   e. Bowel mesentery

5. In patients with rectal injury incurred during radical prostatectomy, colostomy need not be performed in all patients with:
   a. Rectal injury >4 cm
   b. Devitalized rectal wall
   c. Previous radiation therapy
   d. Large amounts of fecal soiling
   e. Thermal injury

6. Following an uncomplicated robotic-assisted radical prostatectomy, large-volume drain output is noted. Chemical evaluation of drainage is consistent with urine. The urethral catheter is draining and irrigating well. The next step is:
   a. Observation
   b. Place larger urethral catheter
   c. Place suprapubic catheter
   d. CT urogram
   e. Cystogram

7. Three weeks following robotic-assisted laparoscopic radical prostatectomy, a 62-year-old man presents with left lower extremity swelling, amd pain on ambulation and adduction. Imaging demonstrates a 12-cm, multi-loculated fluid collection in the left iliac fossa, compressing the left iliac vein. Venous duplex demonstrates no evidence of deep venous thrombosis. The next step is:
   a. Bed rest, leg elevation
   b. Percutaneous aspiration
   c. Percutaneous drain placement
   d. Drainage and sclerosis
   e. Laparoscopic marsupialization

8. An absolute contraindication to robotic-assisted laparoscopic radical prostatectomy (RALRP) is:
   a. Previous intraabdominal surgery
   b. Renal transplant
   c. Obesity, with BMI >35
   d. Inability to tolerate Trendelenburg position
   e. Abdominal wall mesh

9. During robotic-assisted laparoscopic radical prostatectomy, the dorsal venous complex is divided. Moderate bleeding is encountered and the insufflation pressure is increased. The patient's oxygen saturation drops, end-tidal CO_2 increases, and blood pressure precipitously drops as well. The next step is:
   a. Undock and reduce Trendelenburg position
   b. Increase insufflation pressure and complete venous repair
   c. Desufflate and increase ventilatory pressure
   d. Desufflate and place in left lateral decubitus position
   e. Convert to an open procedure

10. In positioning a patient in the supine Trendelenburg position for RALRP, support is needed to prevent injury of the:
    a. Cervical spine
    b. Peroneal nerve
    c. Gluteal muscle compartment
    d. Brachial plexus
    e. Calf muscles

Case Study 1

A 70-year-old male undergoes an uncomplicated robotic-assisted laparoscopic radical prostatectomy. Following surgery, his pelvic drain is noted to have an overnight output of 350 mL of serosanguinous fluid. His urethral catheter has an output of 300 mL. The following morning, his drain output persists.

1. The next step is:
   a. To check creatinine level from drain
   b. A cystogram
   c. A pelvic ultrasound
   d. A CT urogram
   e. To irrigate catheter and observe

2. A drain creatinine level is noted to be 35 mg/dL, consistent with urine. The next step is:
   a. Continued catheter drainage
   b. Suprapubic catheter insertion

c. A CT urogram
d. A pelvic ultrasound
e. A cystogram

3. The patient is observed for 3 days without improvement in the volume of his pelvic drainage. A repeat creatinine level from the pelvic drain is 38 mg/dL, consistent with urine.The next step is:
   a. Continued catheter drainage
   b. Suprapubic catheter insertion
   c. A CT urogram
   d. A pelvic ultrasound
   e. A cystogram

Case Study 2

A 63-year-old man undergoes a radical prostatectomy by robotic-assisted laparoscopic approach. The dorsal venous complex is sharply incised, following bladder neck division and prostate mobilization, without suture control prior to incision. Brisk bleeding is encountered, precluding vision.

1. The next step is:
   a. To blindly cut toward the urethra to complete division of the dorsal vein
   b. To insert a second suction device to improve exposure
   c. To increase insufflation pressure
   d. To pack the region and proceed with urethral division
   e. Open conversion

2. After increasing insufflation pressure, sufficient vision is obtained to complete the division of the dorsal vein complex. The prostatectomy is completed after oversewing a number of small bleeding sites in the surgical bed. Following surgery, the patient is noted to be oliguric, requiring several fluid boluses overnight. He is mildly tachycardic with normal blood pressure. His hemoglobin has declined from 13.2 g/dL to 8.9 g/dL overnight. The next step is:
   a. Continued observation
   b. Transfusion, bed rest, serial hemoglobin check
   c. A renal ultrasound
   d. A pelvic CT
   e. Transfusion and re-exploration

3. The most likely source of bleeding is:
   a. Dorsal venous complex
   b. Seminal vesical arteries
   c. Abdominal wall vessels
   d. Neurovascular bundles
   e. Iliac vessel tributaries

Answers

1. **b.** Increasing suction in the face of bleeding will secondarily lower insufflation pressure, thereby increasing bleeding. An increase in insufflation pressure may reduce bleeding enough to visualize the dorsal venous complex, allow completion of division, and allow suture control. Stapling of the dorsal vein complex is ideally performed prior to division. Upon division, it would likely not be feasible to staple the complex. Open conversion of any sort would only be a last resort, if attempts at control of bleeding were unsuccessful.
2. **c.** The aorta and its bifurcation lie directly beneath the umbilical position in most patients and are most likely to be injured during blind port insertion in the typical periumbilical position.
3. **d.** While all the choices reflect potential sources for injury to the bowel, movement of instrumentation, either by the surgeon or the assistant, outside the visual field is most likely to result in an unrecognized injury to the bowel. Careful inspection of the operative field prior to removal of the scope is always wise at the end of each case.
4. **d.** While postoperative bleeding can arise from the iliac vessels or a poorly controlled dorsal vein complex, such bleeding is more likely to result in profound early bleeding, requiring eventual return to OR due to hemodynamic instability. Significant bleeding that does not result in hemodynamic instability, but causes continued decline in hematocrit and abdominal wall ecchymosis, is most likely to arise from the abdominal wall vessels.
5. **e.** While colostomy could be considered in patients with thermal injury to the rectum, it need not be performed as routine, depending upon the size and severity of the injury. Excessive thermal injury may result in devitalized rectal wall, and because this can be difficult to determine, if there is any suspicion based upon the severity of the injury, colostomy might be considered. The remaining choices are all absolute indications for general surgical consultation and colostomy.
6. **a.** In this patient with early postoperative evidence of a urethrovesical anastomotic leak, observation is the most reasonable initial approach. As long as the catheter is draining and well positioned, most controlled leaks will resolve with time. If the leak were to persist or if the patient were to develop further complications such as infection, ileus, or ascites, further evaluation might be warranted.
7. **e.** The patient appears to have a loculated lymphocele that is relatively large and symptomatic. While aspiration or prolonged drainage may alleviate some symptoms, the loculated nature of the collection makes it unlikely that full drainage would be achieved. In this case, marsupialization of the lymphocele would offer the greatest likelihood of durable resolution.
8. **d.** While the remaining choices are relative contraindications to RALRP, the ability to proceed with surgery in these individual scenarios is often dependent upon the surgeon's comfort level and experience. Morbid obesity may lead to an inability to tolerate positioning or access the pelvis upon docking of the robot, but many obese patients can undergo RALRP without a problem. Inability to tolerate Trendelenburg position precludes the ability to successfully proceed with RALRP as the position is largely essential.
9. **d.** The clinical scenario is most consistent with a gas embolus from the insufflation. Increasing insufflation pressures in the face of bleeding may improve vision, but also increases the risk of advancing CO_2 into the venous system. In these cases, immediate desufflation and placement of the patient in the left lateral

decubitus position are desirable. In extreme cases, aspiration of the embolus may be needed, but in general, CO_2 is quickly absorbed.

10. **d.** While injury can occur to any region of the body during positioning, while in the supine position for RALRP, injury to the calf or peroneal nerve is unlikely. The cervical spine should be supported, but undue stretch or twist of the neck is not as great a risk as stretch on the brachial plexus through inadequate or excessive support of the shoulders.

CASE STUDY 1

1. **a.** Increased drain output following robotic-assisted laparoscopic radical prostatectomy can be representative of urine, lymphatic fluid, or peritoneal ascites. Testing for serum creatinine will rule out, or in, a urine leak. While this may not require intervention, it will aide in determining if the drain can be removed.
2. **a.** Most urine leaks in the early postoperative period after robotic-assisted radical prostatectomy can by treated conservatively with catheter drainage. Ultrasound to rule out urinoma and adequate extravesical drainage can be useful if the drain persists beyond the first 7–10 days. Most often, urine leaks will resolve within 1–3 days with adequate drainage. Increasing abdominal distention, fever, or ileus should alert the physician to the possibility of urinary ascites. In some cases, ascites may require additional drainage to reduce related morbidity.
3. **c.** Persistent urinary leakage following radical prostatectomy should caution the managing physician with regard to the possibility of a ureteral injury. While cystogram may demonstrate the extent of urine leak from the bladder, it would not rule out a ureteral injury. CT urogram with delayed sequences is likely to demonstrate any ureteral injury, hydronephrosis, bladder leak, and extravesical urine collections.

CASE STUDY 2

1. **a.** Bleeding from the uncontrolled dorsal venous complex is exacerbated by stretch due to fixation of the complex. This is commonly encountered upon incomplete division of the dorsal venous complex. Increasing suction secondarily lowers insufflation pressure, thereby increasing bleeding. Increasing insufflation can aid with vision, to allow completion of the dorsal vein division. Complete division will likely greatly reduce bleeding in most cases. Caution should be exerted upon increasing insufflation pressure due to the theoretical risk of air embolus. Open conversion would likely only worsen bleeding upon loss of insufflation.
2. **b.** Postoperative bleeding following robotic-assisted laparoscopic prostatectomy, which does not cause hemodynamic instability, generally is self limited and will stop with supportive care, though considerable blood loss can occur prior to cessation. In most cases, pelvic CT will demonstrate blood in the pelvis and subcutaneous tissues, but will not aid in management. If the patient becomes unstable or bleeding persists for more than 1–2 days with supportive care, angiography or re-exploration may be warranted.
3. **c.** Postoperative bleeding following robotic-assisted laparoscopic prostatectomy, which does not cause hemodynamic instability, is most often caused by abdominal wall bleeding from the underlying muscle and branches of the epigastric vasculature.

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33 Complications of Robotic Pelvic Floor Reconstruction

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CHAPTER OUTLINE

Preoperative Considerations
Patient Positioning and Surgical Setup
Intraoperative Complications
Bowel Complications
Hemorrhagic Complications
Urologic Complications
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Postoperative Complications
Infectious Complications
Thromboembolic Complications
Bowel Complications
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De Novo Incontinence
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Chaper 33 Questions and Answers

KEY POINTS

1. Pre-operative risk stratification for robotic pelvic floor reconstruction should be focused on pulmonary compromise, uterine enlargement or pelvic adhesions, and sacral anomalies such as a horseshoe kidney or sacral bony abnormality in order to minimize operative complications of robotic sacrocolpopexy.
2. Pre-operative assessment of clinical or occult stress urinary incontinence enables the pelvic floor surgeon to properly counsel the patient regarding options for concurrent incontinence procedures at the time of robotic sacrocolpopexy, in order to decrease the risk of post-operative persistent or *de novo* urinary incontinence.
3. Proper patient positioning for robotic pelvic floor surgery includes attention to Trendelenburg and its potential to cause nerve injury, retinal injury and pulmonary compromise. Anti-skid techniques should be employed to avoid inadvertent patient movement after robot docking.
4. Pre-sacral hemorrhage is the most significant and potentially life-threatening complication associated with sacrocolpopexy. Meticulous attention during sacral dissection must be carried out with particular knowledge of aberrant sacral vasculature. The most common site of vascular injury is the left common iliac vein and its appearance can be distorted by the pneumoperitoneum, often mistaken for the anterior longitudinal ligament.
5. Intra-operative pre-sacral hemorrhage is often difficult to control with pressure, topical hemostatic agents or materials and generally requires conversion to open with vascular surgery assistance. It is imperative to maintain local pressure on the site of sacral bleeding while conversion is undertaken, initially utilizing the robotic arm followed by a laparoscopic instrument. Communication with anesthesia and nursing staff is imperative during the conversion process in addition to preparation of blood products.
6. Cystotomy during robotic sacrocolpopexy can be avoided by placement of a vaginal manipulator such as a sponge-stick, EEA sizer or vaginal stent to facilitate dissection in the proper plane between the anterior vaginal wall and bladder. Cystoscopy is imperative at the completion of the robotic pelvic floor procedure to ensure there has been no injury to the bladder or ureters.
7. Bowel dysfunction is a common post-operative complaint following robotic pelvic floor reconstruction. Dyschezia, obstructed defecation and constipation re the most common types. The average time to first bowel movement post-operatively is 3 days and patients should be made aware of this expectation.
8. While rare, post-operative infection of the disc or sacral bone can occur and be both severe and potentially life-threatening. Severe back pain accompanied by fever or signs of sepsis should prompt immediate lumbosacral imaging. When placing sacral sutures, the surgeon must avoid the L5-S1 disc space and the depth of sutures in the anterior longitudinal ligament should not exceed 2–3 mm.

As the life expectancy of the population continues to increase, so does the prevalence of medical conditions associated with advancements of age. Pelvic organ prolapse (POP) is a common condition associated with aging, menopause, and prior pregnancy and delivery. Surgical repair of POP is currently the most common type of inpatient procedure performed in women older than 70 years,[1] and the incidence of procedures for this condition will continue to increase.

The abdominal sacrocolpopexy is regarded as the "gold standard" procedure for correcting symptomatic pelvic organ prolapse.[2] In many patients, minimally invasive routes of sacrocolpopexy and other gynecologic procedures are preferred[3,4] and offer advantages both for the patient and the surgeon. Minimally invasive sacrocolpopexy has been compared with the abdominal approach in various studies and has proven to be as efficacious and safe, with the added benefit of decreased morbidity.[5–7] More recently, two level 1 studies have been published comparing abdominal sacrocolpopexy with a minimally invasive approach. Both trials reveal comparative outcomes between the groups and illustrate that the minimally invasive approach is associated with decreased morbidity, less blood loss, shorter length of stay, dand overall decreased recovery time.[8,9] These data support the use of minimally invasive surgical approaches to sacrocolpopexy and other POP procedures.

With minimally invasive surgery comes a unique set of perioperative considerations, counseling topics, and both intraoperative and postoperative complications. Surgeons should be aware of these unique components of minimally invasive surgery and should understand ways to minimize potential obstacles whenever possible. This chapter aims to highlight the potential perioperative complications unique to robotic female pelvic surgery and to discuss how to safely handle these problems should they arise.

Preoperative Considerations

When determining surgical candidacy for robotic reconstructive pelvic surgery, the surgeon must gather critical information during the office evaluation (Table 33.1). It is imperative to focus the history and physical exam around factors that could increase the risk of complications unique to robotic surgery. When considering a laparoscopic or robotic approach, the medical history should include questions about the patient's exercise tolerance, smoking history, presence of cardiopulmonary or chronic renal conditions, and history of prior pelvic surgeries. The surgeon should have a good understanding of the hemodynamic and metabolic effects of intraabdominal CO_2 insufflation on individuals with these conditions. Potential contraindications to laparoscopic or robotic surgery such as an increase in intracranial pressure or baseline hypovolemic state should be contemplated, especially when the operative time may be prolonged. Patients with pulmonary compromise should be particularly counseled on possible conversion to laparotomy if the degree of physiologic strain, such as impairment of pulmonary functional residual capacity, becomes intolerable to the patient during surgery.[10] It is well documented that patients benefit from smoking cessation prior to surgery, and encouraging patients to stop smoking within 8 weeks of surgery can be beneficial. Studies demonstrate improvements in respiratory function and lower risks of postoperative atelectasis and aspiration pneumonia, known risks associated with the inability to tolerate pneumoperitoneum or steep Trendelenberg positioning.[11] While research indicates that pulmonary complications after laparoscopy may be lower than those associated with laparotomy, surgeons should be aware of the specific risks in patients with cardiopulmonary comorbidities, such as chronic obstructive pulmonary disease. Pulmonary complication risk is also found to correlate with older age and longer

Table 33.1 Preoperative Considerations in Robotic Pelvic Floor Reconstruction

Patient History and Physical Exam	■ Thorough assessment of tolerance of abdominal insufflation/Trendelenberg positioning:
	  ■ Smoking history, exercise tolerance, obesity
	  ■ Cardiopulmonary/renal disease
	  ■ Increased ICP
	  ■ Hypovolemic state
	■ Abdominal survey for scars, hernias, and understanding of prior pelvic surgeries, anatomic variants
	■ Uterine mobility, adnexal mass:
	  ■ Lateral mobility ≥2 cm for uterine vessel access
	■ Gentle preoperative bowel prep only when deemed necessary (surgeon preference):
	  ■ Mg citrate, Miralax

Patient Positioning and Surgical Setup	■ Proper use of corporeal padding
	■ Joint flexion at maximum angle of 30 degrees
	■ Anti-skid materials to decrease risk of nerve injury:
	  ■ Pink pad, egg crate, surgical beanbag
	■ Facial padding, eye taping to reduce facial injury:
	  ■ Direct facial trauma responsible for 20% of corneal abrasions
	■ Be mindful of degree of Trendelenberg positioning absolutely necessary:
	  ■ Less steep degree may decrease morbidity without negative effects on surgical time, visibility (Ghomi et al.):
	■ 30-degree camera for optimal sacral visualization:
	  ■ If distance from umbilicus to pubic symphysis <15 cm, camera port should be supraumbilical
	■ Direct visualization and abdominal survey during trocar insertion:
	  ■ Port site bleeding most commonly from perforation of inferior epigastric artery
	  ■ 55% of bowel perforations occur during intraabdominal access
	■ Use of 8-mm or 5-mm accessory port to decrease hernia risk

operative time.[12] These factors should be taken into consideration when deciding upon the route of pelvic reconstructive surgery.

The physical exam should include assessment of abdominal scars and the presence of any abdominal hernias, particularly if a patient has had multiple prior abdominal surgeries. This will allow for anticipation of potential difficulties with port placement and pelvic adhesive disease when planning a robotic surgical approach. Particular attention should be paid to umbilical hernia as the umbilicus is often utilized as a port site during robotic surgery. Additionally, a bimanual pelvic evaluation to assess uterine mobility and size is necessary. One should attempt to palpate the width of the lower uterine segment (LUS) at its junction with the cervix and assess degree of movement of this segment toward the contralateral pelvic sidewall. In general, lateral mobility of 2 cm or more on each side predicts adequate access to uterine vessels laparoscopically. The presence of obstructing fibroids or pelvic adhesions should also be considered, as these characteristics can limit uterine mobility and preclude successful minimally invasive pelvic surgery. Placing cephalad pressure on the LUS and attempting to elevate the uterus out of the lower pelvis can help with understanding of circumferential space that is present. This technique may be inhibited by patient body habitus. At times, pelvic imaging may be necessary to adequately assess uterine size and other pelvic pathology that may make laparoscopy more difficult.

Obesity itself should not preclude minimally invasive surgery; however, it can make a laparoscopic or robotic approach to pelvic surgery more challenging due to the impact of this condition on both respiratory and gastrointestinal mechanics. Obese patients, particularly with a BMI >40, are prone to poor gas exchange and delayed gastric emptying, increasing the risk of impaired respiratory function and aspiration during and after surgery. Obesity also is commonly associated with increased central adiposity, which can preclude optimal patient positioning, trocar placement, and visualization intraoperatively.[13,14] It is imperative to consider these risk factors when counseling patients on minimally invasive surgery, and extra time should be allotted perioperatively to ensure optimization of patient positioning.

The surgeon should inquire about any known anomalies of pelvic anatomy. Anatomic variances such as a horseshoe kidney, transplant kidney, or any sacral anomalies could make robotic sacrocolpopexy more difficult or contraindicated. Knowledge of these potential structural alterations should prompt adequate imaging to obtain a clearer understanding of any variations or abnormalities in pelvic anatomy. Surgeons can then plan for any required modifications in instrument placement or surgical technique when performing pelvic surgery.

Screening for stress incontinence is pertinent when performing any prolapse procedure, and if present, discussion of a possible concomitant anti-incontinence procedure is needed. The surgeon should take into account the risks and benefits of added operative time with concomitant procedures and the potential complications this could pose. Conversely, even without the presence of stress incontinence, the possibility of de novo stress incontinence following sacrocolpopexy should be discussed. Ideally, patients should be screened for occult stress incontinence with prolapse reduction preoperatively to allow for proper counseling and surgical planning. Management of expectations is critical, and patients should be made aware that midurethral sling placement at the time of minimally invasive sacrocolpopexy may be associated with lower incontinence cure rates, when compared to sling surgery alone.[15]

Traditionally, preoperative mechanical bowel preparation (MBP) has been used as a way to enhance visualization of the surgical field and improve intraoperative bowel handling. In theory, this practice leads to a decreased incidence of bowel injury and lowers minimally invasive operative times. More specifically, bowel preparation can facilitate sacral visualization during robotic sacrocolpopexy. Recently there has been evidence in the literature refuting the necessity of mechanical bowel preparation in minimally invasive surgery in gynecology.[16,17] In a recent systematic review of high quality trials across surgical specialties, there were no or few benefits of MBP or rectal enemas and no negative effects on perioperative outcomes were reported.[18] These data should prompt surgeons to contemplate the risk and benefit of MBP when performing minimally invasive prolapse surgery. In surgical procedures where this practice seems beneficial, preparations using magnesium citrate or Miralax combined with 64 oz of Gatorade appear to be the best tolerated.[17] We routinely recommend a modified mechanical bowel preparation preoperatively to enhance pelvic visualization during robotic surgery, minimize the need for bowel manipulation intraoperatively, and improve postoperative return to bowel function. We utilize a clear liquid diet the day before surgery as well as one bottle of magnesium citrate and two doses of oral bisacodyl.

Patient Positioning and Surgical Setup

Intraoperatively there are many techniques that can be adopted to allow a surgeon to decrease the risk of complications when performing robotic pelvic reconstructive surgery (see Table 33.1). It is critical to maintain constant communication between the anesthesia and surgical teams when choosing the most appropriate operating room setup, as each case may require adaptations to the arrangement of room layout, instrument choice, and other ergonomic considerations. For both laparoscopic and robotic-assisted prolapse repair, proper patient positioning is imperative to sustain optimal surgical exposure and prevent neuromuscular compromise. One obvious concern with these surgical techniques is sliding of the patient on the operating table during steep Trendelenburg positioning. This can result in skin breakdown and neuropathic injuries, as well as incisional extensions and formation of hernias through port sites due to the overstretching caused by incidental changes in patient position. Nerve injury is increased in obese patients, who most commonly suffer from ulnar and sciatic neuropathies.[14] The surgeon should ensure proper corporeal padding of both upper and lower extremities. The knees should be flexed at a maximum angle of 60 degrees when patients are placed in dorsal lithotomy position. Any greater flexion increases the risk for femoral nerve compression. Arms should be tucked at the patient's side, and all pressure points should be adequately protected. Leaving the arms

extended or the use of shoulder blocks can increase the risk of brachial plexus injury, and these practices should be avoided.[19] Recent evidence illustrates that use of anti-skid materials such as egg crates, surgical beanbags, or gel pads minimizes the risk of shifting and therefore decreases the potential for nerve stretch injuries, even in patients with a BMI >30.[20] After the anti-skid material is placed on the operating table, the patient should be placed directly on this material without intervening bedsheets. This direct contact allows for optimal drag coefficient to keep the patient from slipping and is very effective for steep Trendelenburg positioning during pelvic reconstructive surgery.

The risk of facial trauma and corneal abrasions should also be considered, especially when performing robotic surgery. The patient's face can be in close proximity to the robotic camera system and instruments, especially when port sites are placed superior to the umbilicus or when using a 30-degree down scope in steep Trendelenburg position. In these instances the robotic camera system may be only a few centimeters away from the face, and facemasks or adhesive eye shields should be used to protect from facial trauma. Direct trauma is known to be the cause of up to 20% of corneal abrasions, and most are thought to be due to lagopthalmos, or failure of complete eyelid closure.[21] To protect this perioperative complication, the eyes can be taped closed after induction of anesthesia. It is important to consider these potential adverse events and discuss ways to minimize risk with the anesthesia team.

Whether performing laparoscopy or robotic-assisted pelvic surgery, the utilization of Trendelenburg positioning is traditionally noted to be essential to achieve adequate pelvic and sacral exposure. Compared with traditional laparoscopy, robotic surgery has been associated with the use of more pronounced Trendelenburg positioning. Although there is no consensus in the medical literature as to the appropriate amount of Trendelenburg used in pelvic surgery, experts have routinely called for "steep" Trendelenburg positioning, usually categorized as 25 to 45 degrees. While this has long been the routine positioning of patients undergoing robotic pelvic surgery, recent data have suggested that gynecologic surgeries can be effectively performed without use of this steep angle positioning, which is often associated with increased morbidity, especially in the elderly or obese populations. In a recent article by Ghomi et al., 20 women underwent robotic-assisted gynecologic surgery for benign disease. The procedures included total and supracervical hysterectomy as well as sacrocolpopexy. Surgeons were blinded to the degree of Trendelenburg used, but were instructed to choose the degree of positioning that would allow them to obtain adequate exposure of the surgical field. Degree of Trendelenburg was measured at the end of each case and results revealed the mean Trendelenburg position used was 16.4 degrees and no patient was placed further than 24 degrees. There were no incidences of conversion, no perioperative complications, and average BMI was 28.5, while median console time was 87.5 minutes.[22] Though the only study of its kind, these data defy the practice of routine adherence to steep Trendelenburg positioning if not absolutely necessary and surgeons should take care to individualize patient positioning for each case in order to minimize complications associated with a considerable degree of Trendelenburg placement. Extra caution should be taken in any patient with retinal disease or prior retinal surgery, as Trendelenburg positioning has been associated with retinal complications in some reports.

Having a clear understanding of abdominal wall anatomy is crucial for proper port site placement, in order to avoid vessel injury during this portion of the case. Both robotic and laparoscopic ports are generally placed in either a W configuration or in a straight line, a minimum length of 10 cm apart, to allow for adequate space and optimal utilization of all ports and to minimize arm collisions. To optimize visualization of the sacral promontory, the camera port should be placed above the umbilicus if the distance from the umbilicus to the pubic symphysis is less than 15 cm. The use of a 30-degree (up) robotic camera to place the four additional ports is often helpful to adequately evaluate the pelvis for any intrusive adhesions and also to position ports properly and ensure avoidance of epigastric vessels. Port site bleeding is noted to occur at an incidence of about 0.7%,[23] and the origin is most commonly due to perforation of the inferior epigastric artery. If perforation does occur it is best to leave the offending trocar in place to denote the location of the injured vessel. If each end of the transected vessel can be identified, cauterization of both ends using bipolar cautery should be attempted. If this is not successful, the method of tamponade using a Foley catheter can be used. A size 10 or 12Fr Foley catheter should be introduced through the 5-mm trocar and inflated with approximately 10–15 mL of sterile water. The trocar is removed only once the balloon has been inflated, and then traction should be applied to allow the balloon to tamponade the port site.[24] Clamping the catheter on steady traction with use of an umbilical clamp or hemostat is helpful, and this can be left in position postoperatively if necessary, until hemostasis is achieved. If neither of these methods will stop port site bleeding, interrupted 0-Vicryl sutures can be placed into the abdominal wall using a CT or CT-1 needle. One suture should be placed on either side of the trocar site and tied externally. These sutures can be removed after 12–24 hours of observation, and the trocar should be left in place during this time.

The use of an 8-mm accessory port is our preference, as the literature reveals a smaller accessory port results in less postoperative pain and decreased risk of port sight hernias when compared to larger accessory ports. In a survey conducted by the American Association of Gynecologic Laparoscopists, port site hernias were found to occur in port sites 10 mm or larger in 86% of cases, while those 8 mm or smaller were associated with only 3% of port site hernias reported.[25] More recently, Paraiso et al. discussed the notion of lower postoperative pain with use of smaller ports when comparing postoperative pain scores in patients undergoing robotic and laparoscopic prolapse surgery. Those undergoing laparoscopy endured fewer and smaller trocar incision sites, which correlated with lower postoperative pain scores.[26] Given this, we routinely use the smallest size ports necessary when performing minimally invasive pelvic organ prolapse surgery. For robotic sacrocolpopexy, once ports are placed and the robot docked, introduction of robotic instruments should be done under camera visualization in a 3, 2, 1 consecutive order to increase efficiency; it can be difficult to rotate the camera to visualize placement of arms 2 and 3 if arm 1 has already been placed. Lastly, each arm's range of motion should be thoroughly assessed to minimize arm collisions during robotic pelvic surgery.

Many of these technical issues have been overcome with the new da Vinci Xi robot, which has a much smaller and lighter weight camera and slimmer arms allowing more range of motion and less problems with clashing.

Intraoperative Complications

BOWEL COMPLICATIONS

Unique intraoperative complications associated with robotic pelvic floor reconstruction can be avoided with knowledge and prevention as outlined here (Box 33.1). During robotic sacrocolpopexy, it is our preference to begin with the dissection of the sacral promontory, in order to complete the more difficult portion of the surgery first. The 30-degree (down) camera is preferred by some surgeons, allowing for better visualization of the sacral promontory. This portion of the procedure requires adequate retraction of the sigmoid colon toward the left pelvic sidewall, in order to maintain optimal visualization of the sacral promontory. Prior to mobilization, however, the surgeon should thoroughly survey the abdomen and maneuver the small intestine into the upper abdomen if steep Trendelenburg positioning has not already accomplished this. Bowel injury during pelvic surgery, although occurring in only about 0.5% of cases, most commonly occurs in the small bowel at the time of intraabdominal access (55%), and delay in identification of a bowel injury can result in mortality in an average of 3% of cases.[27] For this reason, it is imperative to be mindful of this complication and take extra time to evaluate for any potential injury during abdominal entry. If a puncture injury of the bowel is identified, a step-by-step inspection of the entire bowel is recommended to ensure no additional injuries are present. The most common cause of nonentry-related bowel injury is usually due to thermal defects, and these are more likely to go unnoticed.

Small serosal or muscularis defects should be repaired using 3-0 delayed absorbable sutures in a two layer, imbricating technique.[28] Recently, barbed suture has also been used for repair of bowel and bladder injuries with good results. This has been described with use of a single layer of 3-0 barbed suture for seromuscular injuries, while two layers of 3-0 barbed suture are used for full-thickness defects. Additionally, some surgeons will use one layer of barbed suture for repair, followed by a second layer of continuous or interrupted delayed absorbable suture.[29] During small bowel repair, sutures should be placed perpendicular to the long axis of the intestine to prevent stricture formation. Conversely, large bowel enterotomies should be repaired with care to avoid any tension on the tissue. Given the larger lumen at this level, stricture formation is less likely; however, any suture tension at the level of the rectosigmoid colon could compromise the integrity of the repair. Although some injuries can be repaired laparoscopically, a number of bowel injuries may require laparotomy.[27] It is important to confer with colleagues intraoperatively at the time injuries are identified, as resection and temporary diversion may be required in some cases.

Avoidance of the above complications can be maximized with proper patient positioning in Trendelenburg, proper mobilization techniques, and use of blunt tools for assistance. The small bowel should always be reflected first so that the large bowel can then secure hold of the small bowel out of the pelvis. Use of fan retractors may also prove helpful in laparoscopic procedures. In the obese patient, there may be redundant rectosigmoid colon, requiring cephalad mobilization and/or retraction. Scheib et al. has described use of an accessory stitch placed through the epiploic appendices and subsequent suspension of the colon to the anterior abdominal wall or left upper quadrant to remove the bowel from the operative field. The ENDOLOOP ligature can also be used in a similar fashion and can be drawn out through ports and secured temporarily.[14,30]

Box 33.1 Intraoperative Considerations in Robotic Pelvic Floor Reconstruction

- Port Site Bleeding
  - Attempt to cauterize injured vessel with offending trocar in place
  - Tamponade can be attempted using a 12-Fr Foley catheter through trocar
  - Sutures can be placed at each side of trocar site and tied externally with removal after 24-48 h
- Bowel Injury
  - Use of fan retractors, accessory stitch, ENDOLOOP ligature to retract bowel effectively
  - If injury detected, Vicryl or barbed suture can be used for repair
  - Repair should be performed in two layers with sutures placed on the long axis of intestine to prevent stricture
- Presacral Hemorrhage
  - Middle and lateral sacral vessels should be well delineated
  - Assess for variability of sacral/iliac vessels, particularly on the left side of anterior longitudinal ligament
  - Apply direct pressure with a Ray-Tec or cottonoid as first-line treatment
  - Hemostatic agents (Floseal, Surgicel) and laparoscopic vessel fasteners should be readily available
- Urinary Tract Injury/Vaginotomy
  - Use of EEA sizers or vaginal stents to allow for proper visualization of vesicovaginal junction
  - Dissection of this junction should be bloodless if correct plane has been identified
  - 25-mg ICG in 10 mL sterile H_2O can be injected into ureters prior to RASC for ureteral identification
  - Bladder/vaginal injury should be repaired in a double, imbricating layer using Vicryl or barbed suture
  - Mesh should not be placed directly over vaginotomy site, should one occur

HEMORRHAGIC COMPLICATIONS

Another significant complication of robotic prolapse surgery, namely sacrocolpopexy, is that of presacral hemorrhage. Although rare, this complication can be life threatening and it is imperative to identify the middle and lateral sacral as well as common iliac vessels, the most common sites of hemorrhage in sacrocolpopexy. Although robotic sacrocolpopexy has been associated with lower overall blood loss when compared to both abdominal and laparoscopic approaches, a recent meta-analysis reported a 0.4% incidence of intraoperative vascular complications, namely left iliac venotomy, with both laparoscopic and robotic

approaches to sacrocolpopexy.[31–33] With this in mind, the surgeon should make it a priority to properly identify the sacral promontory as a landmark, which is best identified just below the bifurcation of the common iliac arteries (Fig. 33.1). The assistant surgeon should be utilized to help with tactile feedback during this process. When incising the peritoneum overlying the promontory one should be cognizant of the variability of the vascular pattern of the presacral space. There can be significant variability in the location of both sacral and iliac vessels, particularly on the left side of the anterior longitudinal ligament of the sacrum.[34] Many surgeons prefer to expose the ligament and vessels thoroughly in a layer-by-layer fashion, in order to minimize injury. The left common iliac vein has a highly variable course and can be difficult to identify as it often appears flat and white due to the effects of the pneumoperitoneum and can be easily confused for the anterior longitudinal ligament.

If presacral vascular injury is encountered, it has been well documented that conventional hemostatic measures have often proven to be futile, probably due to the increase in hydrostatic pressure when in lithotomy position, as well as the fixed nature of the venous plexus to the sacral periosteum. When the hemorrhage is identified it is important to communicate effectively with the operative team and immediately apply direct pressure to the area with the nearest blunt robotic instrument. A RAY-TEK or cottonoid sponge can be passed into the field by the side surgeon and this can also be used to apply direct pressure for a minimum of 5 minutes. If the bleeding persists, topical hemostatic agents should be considered. Germanos et al. described three cases of presacral hemorrhage that were successfully managed using a combination of a hemostatic matrix (Floseal; Baxter, Hayward, CA), which should be directly applied over the area of bleeding, followed by application of an absorbable hemostat (Surgicel Fibrillar; Ethicon, Somerville, NJ) that is applied over the top as a pad.[35] Topical hemostatic agent use should be accompanied by temporary pressure applied with gauze to secure the hemostatic matrix. Laparoscopic tacks or clips can also be placed and should be readily available in anticipation of vascular injury. Another method described in the literature utilizes absorbable hemostat material (Surgicel), which is then secured in place using laparoscopic fasteners. These fasteners are then anchored to the sacrum to apply targeted pressure to the bleeding area.[36] These techniques can only be utilized for relatively small sacral vessels. In the case of a common iliac venous injury, formal vascular repair is critical to stop hemorrhage.

When these minimally invasive approaches fail, the surgeon should be prepared to convert to an open procedure. If a robotic approach is underway, the team should have an "emergency undock" protocol in place. The surgical and anesthesia teams should always be in constant communication regarding extent of blood loss and potential need for transfusion protocols to be activated. While preparing for conversion to laparotomy, pressure using a gauze, cottonoid, or blunt instrument must be maintained to prevent further hemorrhage. This can be accomplished with a robotic arm followed by a laparoscopic instrument through an accessory port when the robot is being undocked. Blood products should be ordered and brought to the operating room. Vascular instruments should be prepared and intraoperative vascular surgery consultation requested.

UROLOGIC COMPLICATIONS

Urinary tract injury, although rare, is a conceivable complication of robotic prolapse surgery, and many genitourinary injuries go unrecognized at the time of the procedure. Minimally invasive sacrocolpopexy has been associated with an intraoperative bladder injury rate of 0.4–3.3% and up to 10% in patients with post-hysterectomy vaginal vault prolapse.[32,37] While some of this could be due to the learning curve associated with newer robotic-assisted techniques, it is important to recognize the possibility of bladder injury and to be prepared to identify and attend to this complication, should it occur. Ureteral injury does appear to occur less frequently, and there is a paucity of literature to determine exact ureteral injury rate during laparoscopic prolapse repair specifically. That being said, laparoscopic hysterectomy has been most recently associated with a ureteral injury incidence of 0.02–0.54%, and incidence does not significantly differ between subtotal and total hysterectomy.[38,39]

In order to minimize risk of genitourinary injury, the surgeon should develop a command of the anatomy and knowledge of the most common sites of injury. Additionally, preoperative risk stratification and intraoperative assessment of ureteral and bladder integrity is essential in preparing for and preventing urinary tract complications. It is imperative to address patient-specific risk factors, such as prior pelvic surgical history and anomalous anatomy. History of three or more previous cesarean sections comes with a cystotomy rate of 20% in the setting of laparoscopic hysterectomy.[40] With regard to type of injury, the dome of the bladder is most commonly involved in injury during total hysterectomy, while the most common sites of ureteral injury occur in close proximity to the uterine artery or at the pelvic brim, near the infundibulopelvic ligament. Identification of the vesicovaginal junction is crucial to avoiding bladder injury. The placement of a sponge stick or end-to-end anastomosis (EEA) sizer vaginally can help with mobilization of the vagina and detection of the plane between the vagina and bladder. This dissection should be bloodless, and areolar tissue should be easily identified. If bleeding is encountered, the surgeon should suspect compromise of bladder wall integrity. Bladder insufflation can also prove helpful during this time to ensure proper dissection. If bladder injury occurs, a double layer closure should be performed with 2-0 or 3-0 absorbable sutures after dissection is complete. Bladder repair can also be successfully performed with barbed suture or a combination of the two types.[29] Subsequently a retrograde fill of the bladder should be performed to ensure adequate closure. We recommend indwelling catheter placement for 5–14 days, depending on the size and location of the defect.

Transperitoneal identification of the ureter can usually be performed at the level of the pelvic brim, and the ureter can be coursed from this point. This technique should be routinely performed whenever possible to decrease risk of ureteral injury; however, in patients with aberrant anatomy or those who have had multiple abdominal surgeries, this may be difficult. In these instances, use of prophylactic ureteral catheterization may reduce the risk of injury during

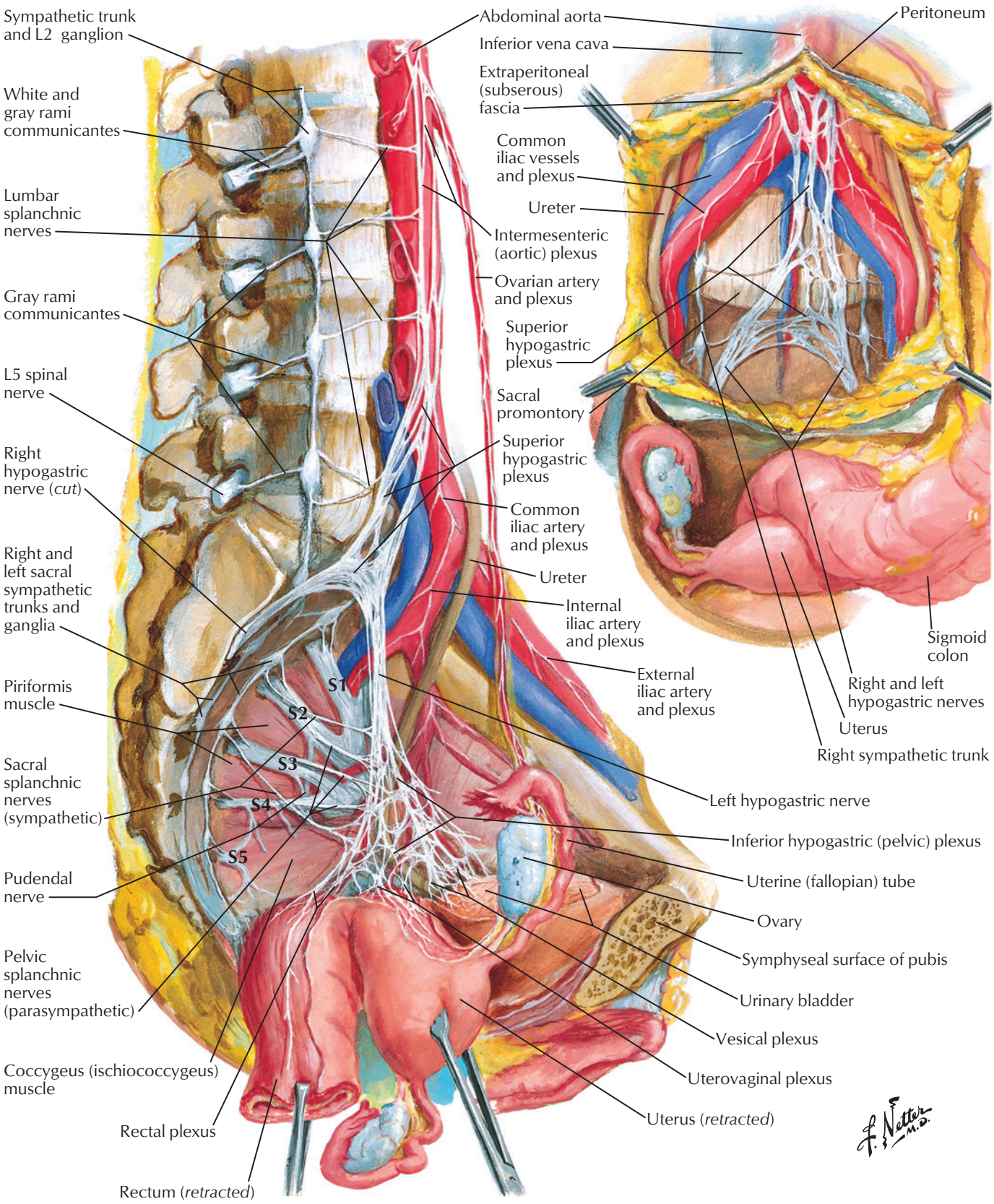


Figure 33.1 Sagittal and coronal depictions of sacral promontory vascular anatomy. (From Netter's Atlas of Human Anatomy. 6th ed. 2014 © Elsevier; Plate 389)

high-risk procedures, although routine use is debated and this practice should not take the place of meticulous surgical technique.[41] Recently, Siddinghi et al.[42] described the use of indocyanine green (ICG) to identify ureters intraoperatively. Prior to the start of surgery, 25 mg of ICG was dissolved in 10 mL of sterile water and injected into each ureter through a 6Fr ureteral catheter. The ICG injection resulted in reversible staining of ureters through protein binding for the entirety of each of 10 gynecologic surgeries. There were no adverse events described at the time of the operation or up to 2 months postoperatively, and cost was approximated at $100 per 25 mg of ICG. This technique can be utilized in anticipation of abnormal anatomy or high-risk prolapse cases when performing robotic-assisted prolapse repair; this technique should be considered as part of one's armamentarium when treating patients with risk factors for urinary tract injury, such as those with diagnoses of endometriosis, multiple abdominal surgeries, ectopic ureter insertion, or duplication of the urinary collecting system. If ureteral injury is identified intraoperatively the ureter should be adequately mobilized and the injured segment excised prior to ureteroureterostomy using 4-0 absorbable sutures. Intracorporeal or cystoscopic placement of a ureteral stent can then be performed. Good success rates of this repair have been described using robotic techniques;[43] however, ureteral repair may require ureteral reimplantation or laparotomy at times.

VAGINAL COMPLICATIONS

Lastly, vaginotomy has been quoted as a fairly common complication of minimally invasive POP repair and has been associated with an incidence from 0.4% up to that of 24% in robotic-assisted sacrocolpopexy with patients who had post-hysterectomy vaginal vault prolapse.[32,33] The presence of this complication has been associated with postoperative vaginal mesh exposure, and for this reason it is of utmost importance to take precautions when performing vaginal dissection.[44] To minimize vaginotomy risk, an EEA sizer or vaginal stent can be placed in the vagina and elevated cephalad either anteriorly or posteriorly by the assistant. This allows the surgeon at the console to delineate vesicovaginal and rectovaginal planes appropriately when performing the vaginal dissection. In cases of post-hysterectomy vaginal vault prolapse it is important to also be mindful of the cuff closure site, as this is usually the area of thinnest peritoneum. Dissection in this area should be only performed after a clear plane has been identified, as vaginotomy is more likely to occur here.[45] It is our preference to leave the peritoneum intact whenever possible, and we routinely forego dissection of the posterior peritoneum from the cervical stump when performing supracervical hysterectomy robotically. We prefer to maintain the peritoneal integrity here to reduce risk of mesh extrusion, as it is felt additional dissection in this area is not significantly helpful. In cases where vaginotomy does occur it is imperative to reinforce this area with a second imbricating layer of suture. Additionally, mesh should not be placed directly over any vaginotomy site. We routinely continue to perform supracervical hysterectomy with sacrocolpopexy rather than total hysterectomy to further minimize mesh exposure or extrusion risk, unless the patient has known cervical pathology or some other medical indication requiring removal of the cervix. Gore-Tex sutures are preferred for anterior and posterior mesh fixation, as their monofilament structure makes vaginal extrusion less likely.

Postoperative Complications

Although overall morbidity remains lower and recovery time is usually shorter in the setting of comparable success rates with an open approach, postoperative complications do occur with robotic sacrocolpopexy.[6,8,9,32,37,46] It is important to recognize those that occur most often, so that one may anticipate these complications and address them in a timely fashion (Box 33.2).

INFECTIOUS COMPLICATIONS

Postoperative surgical site infection (SSI) is found to occur at a rate of approximately 2–4% during minimally invasive hysterectomy and sacrocolpopexy procedures, and this complication is associated independently with intra/postoperative blood transfusion and longer operative time.[37,47] These characteristics are likely representative of longer, more complicated surgeries. Possible reasons for wound infections could include failure to redose antibiotics during longer cases, prolonged tissue and or trocar manipulation, increased risk of violation of sterile technique, and larger potential for thermal or glycemic disregulation. The surgeon should always be mindful of the time

Box 33.2 Postoperative Complications in Robotic Pelvic Floor Reconstruction

- Surgical Site Infection
  - Cephalosporins should be redosed intraoperatively after 4 hours or with >1500 mL blood loss
  - Patients >120 kg should receive a 3-g initial dose instead of standard 2-g dosing when using cefazolin
  - Postoperative antibiotics for wound infection should be targeted at gram-positive bacteria
- Venous thromboembolism (VTE)
  - LMWH should be considered in patients >60 yr, as they are deemed "high risk" with VTE risk 20–40%
- Bowel Complications
  - Dyschezia, obstructed defecation, and outlet constipation are the most common types of postoperative bowel dysfunction, and patients should not expect a bowel movement within the first 3 days after surgery
  - Extensive dissection of rectovaginal septum should be avoided to reduce bowel denervation
- Mesh Complications
  - Mesh should be placed as flat as possible and against sacral promontory to decrease anorectal dysfunction
  - Supracervical hysterectomy is preferred to reduce mesh extrusion rates
  - Use of lightweight type I mesh to reduce risk of graft infection
- De Novo Stress Urinary Incontinence (SUI)
  - Vaginal examination should be performed intraoperatively to assess for anterior/apical overcorrection which could lead to new onset SUI

and discuss potential need for redosing of antibiotics with the anesthesia team. Antimicrobial prophylaxis guidelines should be reviewed. Most often, cephalosporins are used for minimally invasive POP repair. In general, redosing should occur after 4 hours or with >1500 mL blood loss. Additionally, patients over 120 kg should receive 3 g initially instead of the standard 2-g dosing. Operating room assistants should also assist with periodic evaluation of trocar sites or need for repositioning to decrease tissue damage during the case that could lead to SSI postoperatively.[48] If wound infection does occur, antibiotics to cover gram-positive organisms should be initiated, as these organisms are most commonly associated with SSI in those individuals undergoing gynecologic/urogynecologic procedures.[49,50] Any area of erythema around the surgical site should be clearly demarcated. Although the routine use of preoperative antiseptic scrubs has been debated, there is evidence to show that this technique reduces the rate of antibiotic-resistant SSI, and use may be considered in patients with predisposing risk factors to wound infection.[50–52]

THROMBOEMBOLIC COMPLICATIONS

Another postoperative complication to be aware of is that of venous thromboembolism, which is thought to come with a risk of approximately 14% in gynecologic surgery for benign disease.[53] Although there is no consensus on venous thromboembolism (VTE) prophylaxis for patients undergoing pelvic reconstructive surgeries, it should be noted that many of these patients are defined as "high risk" solely on the basis of age >60 years, which comes with a general VTE risk of 20–40%.[54] Both the AUA and ACOG recommend the use of anticoagulation in "high risk" populations undergoing high-risk surgeries such as vaginal wall repairs and sacrocolpopexy.[55,56] Given the average age of the patient undergoing POP repair, strong consideration should be given to these recommendations, and the benefit of heparin intraoperatively should be weighed against individual bleeding risk. That being said, the use of pneumatic compression devices should be employed routinely, independent of other anticoagulation, unless the patient has a contraindication to this. If a VTE is suspected, the patient's pre-test probability should be calculated and diagnostic tests should be performed. Davis[57] provides a concise review of clinical models used for diagnosis and treatment of VTE in gynecologic surgery. These algorithms can be helpful when choosing treatment method and duration for patients.

BOWEL COMPLICATIONS

Bowel complications after minimally invasive sacrocolpopexy can range from very painful constipation to bowel obstruction secondary to adherence of intestines to exposed abdominal mesh. While bowel obstruction rates are rare, ranging from 0.4% to 1.7%,[37] overall rates of bowel dysfunction far surpass this, with an incidence rate of 5–14% in a recent meta-analysis of robotic-assisted sacrocolpopexy. The most common types of dysfunction cited were dyschezia, obstructed defecation, and outlet constipation.[31] Recent studies suggest that having concomitant posterior prolapse repair does not increase bowel dysfunction rates, and these symptoms may be related to surgical technique of sacrocolpopexy.[58] It is imperative to place the mesh as flat as possible against the sacral promontory and to avoid attachment to the levator ani musculature in order to decrease anorectal dysfunction postoperatively. Extensive dissection in the rectovaginal septum should be avoided to reduce the risk of rectal denervation injury. Additionally, management of expectations is important in this area. Patients should understand that average time to first bowel movement (BM) is estimated at 3 days after prolapse surgery, and a recent RCT revealed no difference in average time to BM with a more rigorous bowel regimen. Additionally, bowel movements were comparatively painful in both groups and those with higher incidence of postoperative narcotic intake had higher postoperative pain scores associated with bowel movements.[59] These data are compelling, and clearly more research in this area is indicated. Since there is no consensus in the literature for bowel dysfunction reduction, we use various techniques to attempt to mitigate this postoperative issue. In order to reduce narcotic use, which is a known contributor to constipation, we implement the use of ketorolac every 6 hours as a standing regimen with narcotics only for breakthrough pain. When transitioning to PO regimen, patients are encouraged to use 800 mg of ibuprofen or 1 gm of acetominophen every 8 hours. Additionally, patients are started on twice daily stool softeners and a powder laxative 1–2 times daily postoperatively and encouraged to continue this regimen until BMs are regulated.

Nausea and emesis should always provoke the question of ileus or small bowel obstruction postoperatively. Often this can be managed conservatively with clear liquid diet or nasogastric tube. At times obstruction persists requiring reoperation, and the decision about this intervention should be made on a case-by-case basis. Surgical technique may again contribute to an obstruction of the bowel, and debate exists about whether obstruction is, in most instances, directly related to mesh placement or exposure. In a recent review, surgeons found similar obstruction rates with and without re-peritonealization of sacrocolpopexy mesh.[60] Conversely, one case series demonstrated two cases of delayed obstruction to be directly attributable to the barbed suture used to re-peritonealize the sacrocolpopexy mesh.[61] These are important points to consider. At our institution, we do utilize barbed suture to routinely re-peritonealize sacrocolpopexy mesh; however, we make sure to cinch tissue after each throw of suture to reduce barbed suture exposure, and we routinely cut suture ends flush with peritoneal tissue to decrease the risk of this complication.

COMPLICATIONS RELATED TO SYNTHETIC MESH

Various other mesh complications can also arise, including pelvic pain or dyspareunia, mesh infection, and mesh extrusion. Patients should be extensively counseled on the possibility of these mesh-related complications and the low but present risk of need for reoperation due to mesh complications, which was found to occur at a rate of 2.9% in a recent review article.[62] Mesh extrusion rates associated with minimally invasive sacrocolpopexy hover around 2–3%[33,37] and are shown to be higher with silicone-coated polyester

and polytetraflouroethylene mesh materials.[62] For this reason, use of these mesh types is not recommended. We routinely perform supracervical hysterectomy with minimally invasive sacrocolpopexy to avoid higher rates of mesh extrusion,[62] unless there is a medical indication to remove the cervix at the time of prolapse repair. Although pain and dyspareunia are found to be less with sacrocolpopexy when compared to vaginal prolapse repairs, these issues still do occur. If pain occurs in the absence of mesh extrusion and conservative measures such as analgesics, local hormone therapies, or local antiinflammatory injections fail, reoperation to remove the mesh may be necessary. When evaluating these patients, differential diagnosis should include bowel or bladder mesh erosion, suture erosion, lumbosacral discitis, and osteomyelitis. Possible diagnostic tests should include and not be limited to cystoscopy, colonoscopy, CT scan, and MRI. There are case reports to support the utility of these tools when evaluating postsacrocolpopexy pain.[63]

While extremely rare, back and/or buttock pain accompanied by acute signs of infection could denote pyogenic spondylitis. This class of lumbosacral infections requires immediate attention and can be life threatening. It is imperative to avoid the L5–S1 disc and to localize the sacral promontory and avoid the sacral nerve, which is most commonly found approximately 3 cm from the upper surface of the sacrum and 1.5 cm from the midline.[64] Sutures should be placed at or below the sacral promontory to avoid the disc space, and when this is not possible, surgeons should be mindful of the 1- to 2-mm thickness of the anterior longitudinal ligament and place sutures no deeper than this to avoid the disc itself.[65] This complication may often require reoperation and removal of mesh and suture, followed by a prolonged course of broad-spectrum antibiotics.

DE NOVO INCONTINENCE

Lastly, de novo stress urinary incontinence can occur following sacrocolpopexy in the minimally invasive setting and the need for further intervention with midurethral sling placement in these patients can far exceed 10%.[31] We routinely perform clinical evaluation to assess for occult stress urinary incontinence if the patient does not identify with this symptom profile. Furthermore, we have implemented a "shared decision making" model into our practice, when considering concomitant anti-incontinence procedures in this setting. It is crucial to assess anterior and apical support vaginally at the time of sacrocolpopexy mesh fixation, to ensure that overcorrection of the anterior compartment has not occurred. If there appears to be tension on the tissues of the anterior vaginal wall or splaying of the urethral meatus, adjustment may need to be considered.

Conclusions

Overall, sacrocolpopexy, whether done via a laparoscopic or robotic route, is an extremely safe and effective form of pelvic organ prolapse repair. These modes of surgery are rapidly becoming the new gold standard, as minimally invasive techniques are found to be more appealing to both patient and surgeon. Minimally invasive sacrocolpopexy has comparable profiles of safety and feasibility, parameters that will only continue to improve with enhancement of surgeon efficiency. It is crucial, however, to acknowledge the unique set of complications that may accompany minimally invasive approaches to sacrocolpopexy, so that we may be equipped to avoid surgical pitfalls and optimally prepared to treat complex situations, should they occur. Surgeon understanding of the complications associated with minimally invasive sacrocolpopexy provides for consensus to develop best practices, which can help to decrease the incidence of these complications and increase overall patient satisfaction associated with these procedures.

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Chaper 33 Questions

1. Preoperative relative contraindications to minimally invasive/robotic sacrocolpopexy include all of the following, EXCEPT:
   a. Chronic pulmonary disease
   b. Active smoking
   c. Severe gastroesophageal reflux disease with prior aspiration pneumonia
   d. Obesity
   e. Prior pelvic surgery

2. Concurrent incontinence surgery should be recommended preoperatively to patients undergoing robotic sacrocolopopexy except when:
   a. Patient complains of preoperative stress incontinence (SUI)
   b. Reduction of prolapse with a pessary results in occult stress incontinence
   c. Patient denies stress incontinence and accepts potential risk of postoperative SUI
   d. Physical exam preoperatively reveals stress incontinence
   e. All of the above

3. Lack of attention to intraoperative patient positioning for robotic pelvic surgery can result in:
   a. Hernia formation at port site
   b. Femoral nerve compression
   c. Brachial plexus injury
   d. Corneal abrasion or facial trauma
   e. All of the above

4. Intraoperative bowel injury during robotic pelvic surgery occurs most commonly:
   a. During port placement
   b. During positioning of the small bowel into the upper abdomen
   c. During sacral dissection
   d. During retraction of the sigmoid colon
   e. During supracervical hysterectomy

5. Presacral hemorrhage can be a life-threatening complication of robotic sacrocolpopexy and is most often caused by inadvertent injury to the:
   a. Common iliac artery
   b. Left common iliac vein
   c. Middle sacral artery
   d. Inferior vena cava
   e. Hypogastric artery

6. Sacral vascular injury during robotic surgery can be addressed by all of the following EXCEPT:
   a. Elimination of pneumoperitoneum
   b. Conversion to open surgery
   c. Hemostatic agents applied to sacrum
   d. Laparoscopic bony tacks
   e. Surgical repair of vessel

7. Intraoperative urinary tract injury during robotic pelvic reconstruction occurs most commonly:
   a. In the distal ureter near the trigone
   b. In the midureter near the pelvic brim
   c. In the bladder trigone during anterior vaginal wall dissection
   d. At the dome of the bladder in post-hysterectomy sacrocolpopexy
   e. At the bladder neck during supracervical hysterectomy

8. Postoperative surgical site infection (i.e., port site wound infections) is associated with:
   a. Prolonged operative time
   b. Increased operative blood loss
   c. Failure to redose intraoperative antibiotics
   d. Poor glycemic control perioperatively
   e. All of the above

9. The most common bowel complications postoperatively following robotic pelvic organ prolapse surgery include the following EXCEPT:
   a. Constipation
   b. Upper GI bleed
   c. Bowel obstruction
   d. Nausea and vomiting
   e. Ileus

10. Mesh-related complications associated with robotic sacrocolpopexy include the following EXCEPT:
    a. Vaginal mesh extrusion
    b. Bowel obstruction
    c. De novo stress urinary incontinence
    d. Dyspareunia
    e. Bladder mesh erosion

Answers

1. **e.** Intraabdominal CO_2 insufflation and steep Trendelenburg positioning during robotic pelvic reconstructive surgery have acute hemodynamic effects, which must be considered preoperatively when assessing a patient's risk for surgery. Any conditions that compromise pulmonary function, such as chronic pulmonary diseases, active smoking, and a history of prior aspiration pneumonia, may preclude a patient's ability to tolerate the hemodynamic and pulmonary effects of robotic pelvic surgery. Obesity may limit the ability to achieve adequate pneumoperitoneum and may limit proper positioning for robotic pelvic surgery. Prior pelvic or abdominal surgery does not necessarily eliminate the option of minimally invasive surgery and can be accomplished safely with careful port placement and potential lysis of adhesions.
2. **c.** Patient satisfaction following prolapse repair can be greatly improved by addressing stress incontinence at the time of a planned surgery for her prolapse. Initial evaluation prior to surgery should include assessment of baseline SUI, including both history and physical exam. Advanced pelvic organ prolapse can mask urethral incontinence because as the anterior vaginal compartment descends, there is a kinking effect on the urethra that may prevent incontinence. With

restoration of pelvic support and prolapse reduction, occult SUI can develop. Preoperative evaluation for occult SUI in patients who deny incontinence can be accomplished by at-home pessary use, in-office stress testing with prolapse reduction, or formal urodynamic evaluation with prolapse reduction. If a patient is continent preoperatively (with negative stress testing) and is willing to accept the risk of postoperative de novo SUI, she may choose to forego concurrent incontinence surgery at the time of robotic prolapse repair.

3. **e.** Robotic pelvic surgery requires careful attention to intraoperative positioning prior to robot docking. Both the surgical team and anesthesia should be involved in proper positioning. Adequate protection of the eyes and face is needed to avoid trauma from overlying camera or equipment. Careful tucking of arms is done to prevent traction on the brachial plexus. Lithotomy positioning must avoid overflexion of the knees and overextension of the hips, which can result in femoral nerve injury. Finally, inadequate padding beneath the patient can result in sliding with Trendelenburg positioning, leading to excessive traction at the robotic port sites and potential hernia formation.
4. **a.** Bowel injury occurs in approximately 0.5% of pelvic surgeries and most commonly occurs during entry and port placement. The small bowel is injured most commonly, and lack of recognition of this injury can lead to mortality in 3% of patients. Port placement should be performed carefully and meticulously, with attention to abdominal wall vasculature and with careful inspection visually after camera port placement. Robotic ports should always be placed under direct camera visualization, and removal of the inner obturator after entry into the peritoneal cavity can help to minimize bowel injury during port placement. The surgeon should also ensure adequate abdominal insufflation prior to placement of ports. Any enterotomy should necessitate careful inspection of the bowel and adequate tension-free repair. An intraoperative consultation may be required to determine the ideal method of repair.
5. **b.** Sacral vascular anatomy can be highly variable. Robotic dissection of the sacral promontory lacks tactile feedback and the surgeon must rely upon visual indicators and knowledge of anatomy. The assistant surgeon can also assist in identifying the bony structure with tactile laparoscopic feedback. Dissection should begin caudal to the bifurcation of the common iliac artery, which is visible in most patients. The left common iliac vein has a variable course along the promontory and anterior longitudinal ligament. With pneumoperitoneum the left common iliac vein can be easily mistaken for the anterior longitudinal ligament, as it may appear flat and white. The middle sacral vessels can be avoided by suturing lateral or medial to them or by using monopolar or bipolar cautery to cauterize small vessels in preparation for suture placement in the anterior longitudinal ligament.
6. **a.** Vascular injury during robotic pelvic surgery requires immediate attention and effective communication with the operating room team, including both nursing and anesthesia. Blood products and open surgical instruments should be prepared during attempts to control the bleeding robotically. Hemostatic agents, laparoscopic tacks, and direct pressure can be tried initially. Depending on the extent of vascular injury, conversion to open and direct surgical repair of the injured vessel may be necessary. During conversion and undocking, it is very important to maintain tamponade of the bleeding vessel to prevent severe, life-threatening hemorrhage. Elimination of pneumoperitoneum would worsen the acute bleeding and make conversion very challenging.
7. **d.** Minimally invasive sacrocolpopexy is associated with a risk of bladder injury ranging between 0.4% and 3.3% and up to 10% in patients with post-hysterectomy prolapse. Proper patient counseling preoperatively should include a discussion of this risk and the potential need for a postoperative Foley catheter should cystotomy occur. Ureteral injury occurs less commonly; however, ureteral integrity should be assessed during each case. Steps to minimize risk of cystotomy during robotic sacrocolpopexy include clear identification of the vesicovaginal junction during anterior vaginal wall and vaginal cuff dissection. Placement of a spongestick, EEA sizer, or vaginal stent can aid in this dissection, and the plane of dissection should be relatively bloodless. Bladder distention can also aid in avoiding cystotomy.
8. **e.** Several factors contribute to the risk of postoperative surgical site infections (SSI). Overall, the reported risk of SSI with minimally invasive hysterectomy and sacrocolpopexy ranges between 2% and 4%. Both prolonged operating time and increased blood loss have been associated with an increased risk for SSI. Intraoperative antibiotics need to be redosed according to specific intervals in long cases. Diabetes and poor glycemic control can also contribute to these infections. Generally, second- or third-generation cephalosporins are recommended and must be dosed according to patient weight to achieve adequate blood and tissue levels.
9. **b.** Bowel complaints postoperatively are fairly common following robotic sacrocolpopexy and range between 5% and 14% in a recent meta-analysis. The most common postoperative complaints include dyschezia, obstructed defecation, and constipation. Patients should be counseled that the average time to postoperative bowel movement is 3 days. Postoperative nausea and vomiting may indicate an early ileus versus a bowel obstruction. Management will depend upon the clinical scenario and response to conservative measures such as bowel rest and nasogastric decompression.
10. **c.** Complications with abdominally placed sacrocolpopexy mesh are much less frequent than vaginally placed mesh for prolapse repair. It is important to counsel patients regarding the specific complications that can occur with sacrocolpopexy mesh, including mesh extrusion, dyspareunia, erosion of mesh into the bladder, and bowel obstruction. Careful dissection along the vagina and avoidance of both vaginotomy and cystotomy can help to prevent these complications. Re-peritonealization of mesh can help to reduce the risk of bowel obstruction due to adherence between bowel and exposed sacral mesh. De novo stress urinary incontinence is a risk associated with sacrocolpopexy, but not uniquely caused by the mesh.

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34 Complications of Laparoscopic/ Robotic Nephrectomy and Partial Nephrectomy

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CHAPTER OUTLINE

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Rhabdomyolysis
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Urine Leak
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KEY POINTS

1. In selecting patients for laparoscopic renal surgery, obesity should be cautiously evaluated as it may contribute to ventilatory difficulty, positioning injuries including nerve injury and rhabdomyolysis, and prolonged operative times due to technical difficulty with the surgery.
2. In positioning patients for transperitoneal laparoscopic renal procedures, patients should be placed at a semioblique angle of 45–60 degrees, with the table slightly flexed, and weight distributed to the hip rather than the upper gluteal or presacral compartments.
3. Scoliosis, significant spinal curvature, or a large tumor can alter the aortic anatomy or renal orientations, secondarily creating rotation of the renal hilum, superior mesenteric artery, inferior mesenteric artery, and mesentery, thereby risking inadvertent vascular injury.
4. Injuries to the liver and spleen during kidney mobilization can often be managed with hemostatic agents, argon beam coagulation, and pressure, but these injuries increase the likelihood of postoperative hemorrhage. Injuries to the distal pancreas can usually be managed conservatively with drainage.
5. Large tumors encroaching upon the renal hilum, or hilar lymphadenopathy, can limit early access to the renal artery. In these cases, preoperative angioembolization can be beneficial.
6. Consider CT imaging for patients with disproportionate pain and leukopenia because these findings may be early warning signs of an unrecognized visceral injury.
7. Stapler misfire during minimally invasive nephrectomy is a life-threatening complication and often results from application of the stapler over clips.
8. Selection of candidates for laparoscopic partial nephrectomy can be aided by objective scoring scales such as the RENAL nephrometry score, but the ultimate decision is largely dependent upon surgeon experience and comfort level.
9. Urine leak following partial nephrectomy is generally managed by drainage of the leak and any surrounding urinoma. Stent or nephrostomy placement is only warranted in cases of ureteral obstruction or persistent high-volume leak.
10. Delayed bleeding following laparoscopic or robotic partial nephrectomy is most commonly due to pseudoaneurysm or arteriovenous fistula in the operative bed, and early intervention with angiography and selective angioembolization is advisable.

Since the first report of laparoscopic radical nephrectomy in 1991 by Clayman and colleagues,[1] the indications for laparoscopic and robotic renal surgery have expanded tremendously. Although laparoscopic approaches were initially felt to be most appropriate for benign disease, current indications have extended to malignant disease in the performance of radical nephrectomy, partial nephrectomy, and, depending upon the skill of the operator, locally advanced renal cancers with caval thrombus extension. The utilization of laparoscopic approaches in clinical practice has grown with the integration of laparoscopic training in urologic residency programs, a significant postgraduate training effort for surgeons in practice, and the growth of surgical technologies, tissue adhesives, and robotic-assisted surgical techniques.[2,3]

Robot-assisted renal surgery allows magnified stereoscopic visualization and the use of articulated robotic instruments under precise control. The advent of robot assistance has facilitated the technical performance of laparoscopic procedures requiring reconstruction, for which suturing and increased instrument dexterity is needed. The dissemination of robotic surgery for partial nephrectomy in the United States has been rapid and safe, albeit with greater cost.[4] Hospital acquisition of the surgical robot has been shown to be associated with a greater proportion of partial nephrectomy.[5,6]

Given the considerable morbidity and pain of upper abdominal and flank incisions, the ability to perform renal surgery through laparoscopic techniques has resulted in reduced pain and more rapid convalescence. When performed well, low rates of complication can be achieved, thus further ensuring improved clinical outcomes for patients. Nonetheless, laparoscopic techniques for nephrectomy and partial nephrectom, require operator skill and experience, as well as good surgical judgment in candidate selection. A number of techniques exist for prevention of complications during laparoscopic renal surgery. Knowledge of relevant anatomy and anatomic variations, as well as adherence to fundamental techniques, can avoid a number of common complications. Early recognition and management of complications, when arising, are critical in preserving good outcomes for the patient.

Preoperative Considerations

PATIENT SELECTION

In selecting patients for minimally invasive renal surgery, one must carefully consider factors related to the patient, the tumor, and the individual skill and experience of the operating surgeon. A careful medical history and exam are warranted, as with any other surgery, in order to determine suitability for surgery and the ability to tolerate anesthesia. In patients undergoing laparoscopic procedures, adequate ventilatory reserve is needed to allow insufflation and elevation of the diaphragm. In this regard, significant underlying pulmonary disease, obesity, or anatomic deformity may be a relative contraindication to the laparoscopic approach. In particular, obesity must be considered carefully as it can result in complications related to positioning, ventilation, and tumor/kidney exposure. Anticoagulants are generally discontinued for a week before surgery when feasible as continued anticoagulation increases morbidity during robotic partial nephrectomy.[7] At our institution we frequently continue aspirin during the perioperative period as 81 mg of aspirin is not associated with significantly higher overall bleeding complications.[8] A bowel preparation is done the day before surgery, largely to avoid postoperative constipation.

In considering patients for renal tumor surgery, the surgeon must decide on partial versus radical nephrectomy, open versus minimally invasive approach, and robotic-assisted versus pure laparoscopic technique. These decisions are, to some extent, based upon surgeon experience and preference, but several factors should be considered. Tumor size and degree of local tumor advancement must be carefully considered prior to selection for minimally invasive approaches, but in practice, this consideration is also influenced by operator experience. In the case of radical nephrectomy, we have found that tumors up to 15 cm in size can be extirpated by laparoscopic approach, but this depends upon tumor location, encroachment upon the hilum, and degree of contact with surrounding structures and great vessels. Large tumors encroaching upon the hilum may preclude early access to the renal vasculature and risk significant bleeding in mobilization of the tumor. In these cases, preoperative angioembolization may facilitate laparoscopic excision. Tumors with extension to the vena cava have been successfully resected by laparoscopic approach, but such efforts are highly challenging and require considerable experience and facility with laparoscopic techniques. The oncologic indications for partial nephrectomy are reviewed to some extent in Chapter 38. The decision between partial and radical nephrectomy is no different in minimally invasive surgery than open, and it is largely related to tumor size, focality, and location; host renal function; host age and longevity; and surgeon comfort. The absolute indications include solitary kidney, bilateral tumors, and markedly impaired renal function.[9] In selecting patients for minimally invasive partial nephrectomy, the depth and location of the tumor predicts the difficulty of both the excision and the reconstruction. As most of the complications of partial nephrectomy are associated with reconstruction, one must consider the difficulty and make decisions regarding the approach based upon the surgeon's experience.

The decision to utilize robotic assistance in renal surgery is also highly controversial, and operator dependent. Robot-assisted renal surgery has rapidly emerged as an alternative to laparoscopic surgery for the treatment of renal malignancy. Robot-assisted renal surgery has been shown to be a safe and viable alternative to laparoscopic surgery, providing equivalent early oncologic outcomes and comparable morbidity to a traditional laparoscopic approach. Moreover, robot-assisted partial nephrectomy appears to offer the advantages of less intraoperative blood loss and shorter warm ischemia time, the latter of which may help to provide maximal preservation of renal reserve. In addition, operative parameters for robot-assisted partial nephrectomy appear to be less affected by tumor complexity compared to laparoscopic partial nephrectomy.[10,11] While the benefit of robotic assistance over pure laparoscopy is difficult to measure, due to similar convalescence, we believe that

those procedures requiring reconstruction may benefit from robotic assistance, owing to the greater facility and speed of suturing and the added dexterity of a third arm for the surgeon. As such, we would generally advocate pure laparoscopy for simple nephrectomy, cyst decortication, radical nephrectomy, and any purely extirpative procedure. In the case of nephroureterectomy, the robotic device may allow complete excision of the ureter and bladder cuff without need for open bladder closure, and as such, its use could be considered depending upon surgeon preference. Several large studies have demonstrated that robotic partial nephrectomy confers a superior morbidity profile compared to laparoscopic partial nephrectomy in most perioperative outcomes;[12,13] however, not all studies' findings are consistent.[14,15] It generally appears that robotic partial nephrectomy has a lower rate of conversion to open surgery and conversion to radical surgery, shorter warm ischemia time, smaller change of estimated glomerular filtration rate, and shorter length of stay.[12,13] We have felt the greatest benefit of robotic assistance is in the performance of partial nephrectomy, largely due to the ability to reduce ischemic intervals through more rapid reconstruction, but also due to the ability to incise the renal parenchyma along anatomic lines in a more deliberate fashion, selectively clamp secondary and tertiary branches of the renal artery, and, in select cases, perform off-clamp partial nephrectomy. In general, we have performed all minimally invasive partial nephrectomies, at our institution, using robotic assistance in recent years.

OPERATIVE PLANNING

Upon making the decision to proceed with minimally invasive surgery for nephrectomy or partial nephrectomy, the surgeon must evaluate each case individually to determine the best approach and appropriate procedure. Anatomic considerations are most important, and variation in host renal anatomy must be considered when selecting the optimal approach. Patients with significant scoliotic spinal curvature and secondary rotation of the great vessels and renal hilum are at risk for inadvertent bowel, mesenteric, and great vessel injuries, and anatomy must be carefully evaluated with preoperative CT or MRI angiography prior to surgery (Figs. 34.1A–D). Similarly, anomalous renal vasculature must be identified preoperatively to ensure complete hilar control at the time of surgery (see Fig. 38.1). In particular, supernumerary renal arteries and veins are critical in order to ensure adequate ischemia during partial nephrectomy and to avoid bleeding during nephrectomy. The presence of a retroaortic left renal vein is important, in that, when present, placing the hilum on stretch can be challenging due to the vein crossing posteriorly from the lower pole, tethering the kidney.

In addition to considering the host anatomy, tumor size and anatomy should be carefully studied. Large tumors planned for radical nephrectomy should be evaluated for location, presence of accessory vasculature, and contiguous renal vein tumor thrombus. A lower pole tumor encroaching upon the medial hilar plane can present a particular challenge in that the surgeon may have difficulty in mobilizing the tumor prior to hilar control and is limited in the amount of traction that can be applied in elevating the lower pole, thus impairing hilar exposure. Upper pole tumors generally allow early hilar control, but must be carefully evaluated for presence of splenic/pancreatic/liver adherence or invasion. In some cases, concomitant en bloc organ resection may be required, and with careful planning, it can be achieved laparoscopically. Finally, when tumors are large and encroaching upon the hilum or associated with significant hilar adenopathy, early access to the renal artery may be limited. Preoperative angioembolization may be helpful in those cases. Tumor vein thrombus is best assessed on MRI venogram, but should be suspected on the basis of enlarged renal vein caliber on CT. Tumor thrombi limited to the renal vein can often be managed laparoscopically without difficulty, but those extending to the vena cava require advanced techniques. In these cases, robotic assistance can be helpful, but advanced laparoscopic skills and considerable experience is needed. Technical considerations in caval thrombus extraction are discussed in detail in Chapters 10 and 37.

In the case of partial nephrectomy, tumor location and size correlate with the risk of intraoperative and perioperative complications.[16,17] The depth of tumor invasion in the kidney, tumor size, and relationship to intrarenal structures must be considered. This evaluation has been objectified to some extent by the use of descriptive scoring methods, such as the RENAL nephrometry score.[16,17] In the preoperative evaluation, tumor size, location, endophytic nature, and proximity to the collecting system are examined on preoperative abdominal computed tomography (CT) or magnetic resonance imaging and a RENAL nephrometry score is determined, allowing standardized reporting of renal masses.[18] Both RENAL and PADUA nephrometry scores are associated with predicting warm ischemia time, urine leak, and high-grade postoperative complications after robotic-assisted partial nephrectomy.[16,17,19] The decision for open, versus minimally invasive, technique must be made by each surgeon, based on his/her operative comfort level. At our institution, we utilized robotic-assisted laparoscopic surgery for nearly all partial nephrectomy cases, including those with solitary kidney, significant multifocality, or very centrally located tumor.

A final decision is that of transperitoneal or retroperitoneal laparoscopic approach. Both approaches carry advantages and limitations, and both are easily adapted to the robotic-assisted technique. The location of the renal tumor frequently dictates the surgical approach, based upon the relationship to Brodell's line. At our center, we prefer the transperitoneal approach for all anterior and lateral tumors while employing the retroperitoneal approach for those tumors that are 100% posterior to Brodell's line and located in the mid or upper kidney. Posterior lower pole tumors can be approached in either way, as the lower pole is easily rotated from a transperitoneal approach. Often the angle from retroperitoneal port insertion to the tumor is difficult when using pure laparoscopy to address a lower pole posterior tumor, but robotic assistance can help with this.

The transperitoneal approach allows for a larger working space and more commonly encountered anatomic landmarks. This approach does, however, require bowel mobilization, increasing the risk of bowel injury, particularly with prior abdominal surgery and frequently leading to longer

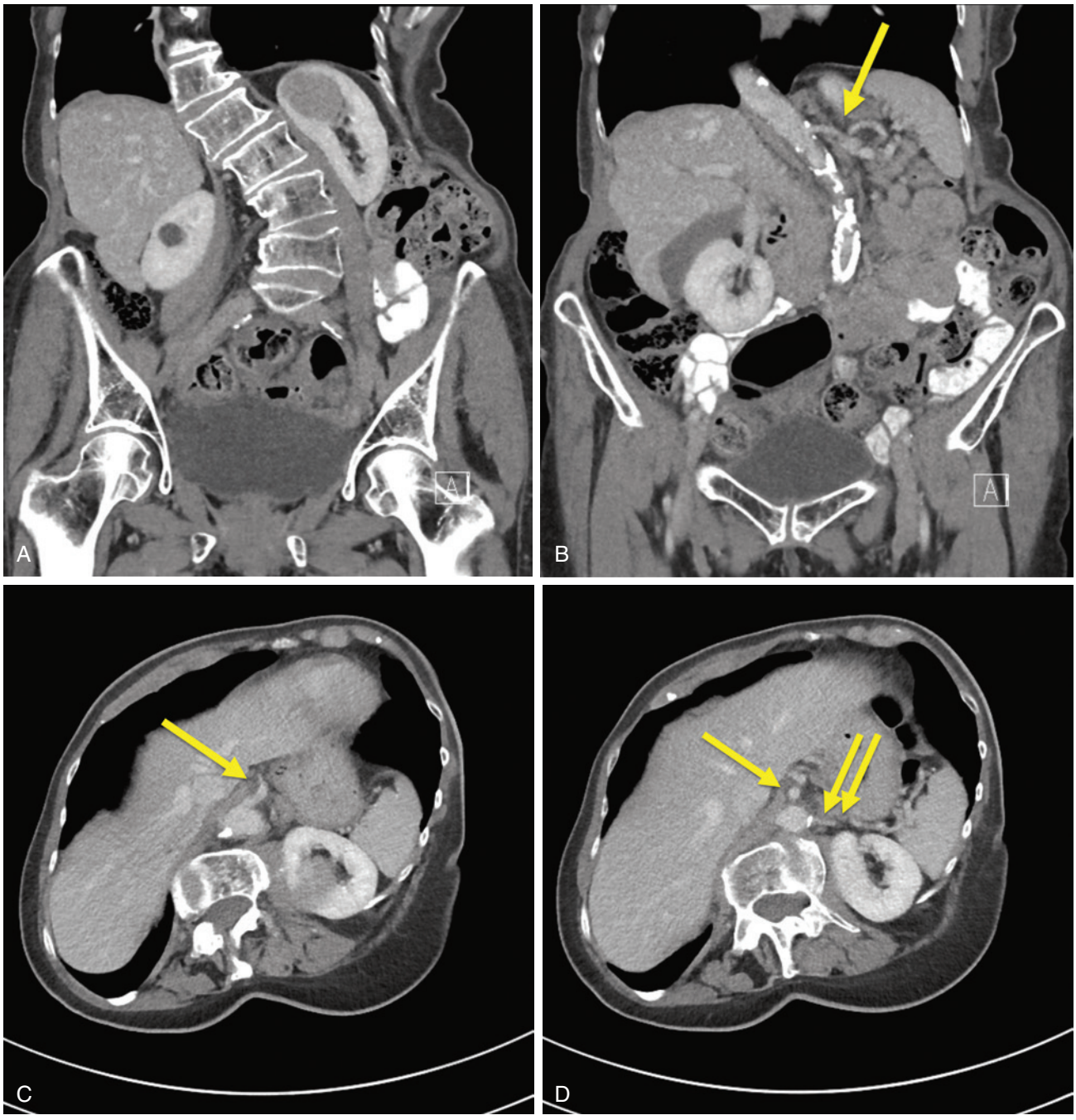


Figure 34.1 A 83-year-old female with severe kyphoscoliotic curvature of the thoracic spine (A) resulting in cranial and medial displacement of the kidney. As a result of the spinal curvature, the aorta is rotated laterally, resulting in a looping renal hilum (single arrow, panel B) with lateral deviation of the celiac trunk (single arrow, panel C) and superior mesenteric artery (single arrow, panel D) and dorsal deviation of the renal artery (double arrow, panel D). In this case, the risk of injury to the mesenteric arteries is high, given the risk of division during renal hilar dissection.

operative times and, ultimately, hospital length of stay.[20,21] The retroperitoneal approach carries a smaller working space, but offers direct access to the posterior surface of the kidney, with lower likelihood of bowel injury and ileus. Previous surgical history may also influence the decision for approach in that intraperitoneal adhesion might be avoided with retroperitoneal access, but in patients with history of previous retroperitoneal surgery, insufflation of the retroperitoneum can result in vascular injuries due to immobility of the vessels and secondary risk of stretch injury.

Procedural Complications

COMPLICATIONS RELATED TO PATIENT POSITIONING

Complications related to positioning are discussed in detail in Chapter 9. Overall, positioning injuries associated with robotic-assisted urologic surgery occur in up to 6.6% of these cases.[22] Positioning complications associated with laparoscopic renal surgery include nerve injuries due to

stretch, most commonly of the brachial plexus, and compartment syndrome with secondary rhabdomyolysis, most commonly of the gluteal compartment. The first reports of minimally invasive renal surgery by a transperitoneal approach described patient positioning in a full flank position with the table flexed. Subsequently, surgeons realized that such extreme positioning was not necessary for exposure, and it increased the risk of neuromuscular injuries.[23] More common now is a modified lateral decubitus position (45 rather than 90 degrees), without table flexion or elevation of the kidney rest. When a retroperitoneal approach is chosen, however, a full lateral decubitus position with the operating room table maximally flexed is often necessary to open up the space between the ribs and the iliac crest (see Fig. 9.5A).

Rhabdomyolysis

Rhabdomyolysis is a rare complication after urologic surgery (0.1%) but is significantly more likely for radical or partial nephrectomy compared to radical prostatectomy.[24] The minimally invasive approach conferred a 1.41 increased OR of rhabdomyolysis. The flank position is associated with higher skin-to-surface interface pressures in men than in women, which has implications for laparoscopic renal surgery and the risk of rhabdomyolysis.[23] Reisiger et al. reported seven cases of rhabdomyolysis after >700 laparoscopic renal procedures (<1%).[25] In a review of six case reports and two case series, 13 patients were reported to have developed rhabdomyolysis in association with laparoscopic nephrectomy.[15] In the setting of a solitary kidney (after laparoscopic nephrectomy), the impact of rhabdomyolysis can be profound; hemodialysis was required in four patients and one developed permanent renal insufficiency.

Prevention of rhabdomyolysis requires careful attention to positioning with avoidance of pressure on the gluteal and presacral compartment. If patients are in the semi-oblique position, they should be placed at a 45- to 60-degree angle to allow pressure to be on the hip rather than the gluteal body or presacral region. This can be particularly challenging in the obese patient. When well positioned, the surgeon should be able to easily pass a hand between the operating table and the upper gluteal region, to the hip.

Patients with gluteal compartment syndrome most commonly complain of unremitting, severe buttock and lower extremity pain upon reperfusion. Most commonly, this complaint is observed in the recovery room, and one should have a very low threshold of suspicion when the complaint is observed. In general, elevation of CPK levels and myoglobinuria lag behind the symptoms. Early intervention with fasciotomy should be considered in order to minimize muscle necrosis. Compartment pressures and cross-sectional imaging are generally noninformative in our experience, and they do not rule out the diagnosis. As swelling in the gluteal muscle increases, lower extremity numbness ensues due to nerve entrapment. In severe cases, the urine may become discolored. Urine myoglobin testing is confirmatory, but early treatment is recommended based on clinical findings. Aggressive intravenous hydration and urine alkalinization can attenuate the impact of rhabdomyolysis on renal function. Risk factors include male gender, muscularity or obesity, and prolonged operative times.[23,25]

Nerve Injuries

Other nerve injuries, including motor or sensory neuropathies, are reported in 1–3% of patients undergoing renal laparoscopy.[26–28] Robotic-assisted surgery is different from laparoscopic surgery in that it often uses more equipment and a steeper Trendelenburg position. Increased injury may be partially due to the robotic arms obscuring the surgeon's view of the patients placing the patient at risk for positioning injuries from slippage or from unrecognized compression from the robotic arms. Neuropraxic injury has occurred in up to 6.9% of robot partial nephrectomies.[22] Brachial plexus injuries can occur if significant pressure is placed on the axilla in the full lateral decubitus position. This complication can be avoided by preventing compression of the axilla with an axillary roll placed under the upper rib cage (but not compressing the axilla) (see Fig. 9.5B). In robotic surgery, we have employed a wedge that supports the upper body, with a carved groove for the lower side arm. This intrinsically protects the brachial plexus. Wrist drop and foot drop can occur when the superior hand or foot are not adequately padded. A rigid arm support attached to the operating room table is more secure than a stack of pillows in terms of supporting the wrist. In recent years, during robotic surgery, we have secured the upper arm to the patient's side in a folded pillow to leave more working space for instrumentation at the upper torso. Foam and pillows are adequate for padding the feet. Careful attention by all members of the operative team to proper fixation of the patient to the operating room table and to padding pressure points before initiating the surgical procedure can help prevent neuromuscular complications.

Neuropathies, usually motor, related to positioning should prompt immediate consultation with a neurologist. Sensory neuropathies are more likely related to the incisions for surgery (even the small ones for laparoscopic ports) or surgical dissection trauma to nerves coursing along the quadratus lumborum and psoas muscles (ilioinguinal, iliohypogastric, and genitofemoral nerves). Incision-related injuries may be unavoidable, but surgical dissection trauma to nerves can be reduced by attention to anatomic features. In most cases, the sensory deficits are transient. Symptomatic improvement while awaiting resolution can be provided by oral gabapentin or amitriptyline.

Other Complications

Testicular or scrotal injuries can result from positioning between the thighs. Scleral edema can develop in the dependent eye. Back or joint pain is not uncommon after a prolonged surgical procedure. Patients with preexisting musculoskeletal pain appear to be more prone to notable postoperative pain in the same locations. Finally, the dependent lung can become atelectatic during a prolonged procedure. In general, many of these complications can be avoided by reducing operative times.

COMPLICATIONS RELATED TO KIDNEY EXPOSURE

Some of the most devastating complications of laparoscopic surgery occur during renal exposure and mobilization. Injury to surrounding vascular structures can be

catastrophic with life-threatening bleeding or organ loss. Delayed recognition of visceral injury can likewise have dire consequences. As such, maintenance of fundamental principles during mobilization is critical, and a keen recognition of anatomy and anatomic variation can avoid unnecessary complications due to injury of surrounding structures.

On the right, exposure requires cranial retraction of the liver and medial rotation of the right colon, duodenum, and, in some patients, the pancreatic head (see Fig. 34.1). Gentle release of such structures through release of fascial attachments and blunt mobilization of the organ can avoid injury. Most often injury results in cases of local adherence of the duodenum or liver due to tumor advancement, peritumoral inflammation, or previous surgery. In such cases, sharp incision is preferable to avoid tearing of adjacent organs during blunt mobilization. On the left, medial reflection of the spleen, left colon, and pancreatic tail is necessary to expose the renal hilum. Wide release of the spleen is advisable in order to facilitate exposure of the upper pole and minimize lateral tethering of the colon. In mobilizing the lateral spleen, injury to the greater curvature of the stomach can occur. Similarly, in injury to the splenic vein or artery can occur if the surgeon wanders medially, out of plane, in mobilizing the medial organs. Maintenance of plane along the ventral surface of Gerota's fascia can avoid such a problem in most cases. In some cases, the splenocolic ligament should be divided to allow more medial exposure of the renal vein and para-aortic space. Excessive traction on the splenic hilum can result in pancreatic tear, adrenal injury, or, if thermal energy is transmitted through the mesocolon, injury to the duodenum at the level of the ligament of Treitz.

While injury to surrounding organs and vessels can occur during any case, most commonly anatomic variation, attributable to body size, habitus, or tumor burden, results in the surgeon becoming "lost" during the dissection and inadvertently crossing to another plane. As an example, rotation of the aorta, occurring in patients with aortic aneurysmal dilatation or spinal curvature, can direct the mesenteric vessels laterally and renal vessels dorsally (see Figs. 34.1A–D), thus resulting in crossing of the mesenteric fold during division of the left renal hilum. Failure to adequately mobilize the upper pole of the hilum can result in misdirection of a vascular stapler across the upper pole of the kidney or the great vessels. Maintenance of perirenal planes in approaching the hilum can avoid inadvertent injury to the vena cava, aorta, or adjacent vascular branches. Previous surgery or the presence of retroperitoneal varices due to portocaval hypertension can likewise create confusion in the operative field.

Vascular Injury

On the left side, the gonadal vein typically drains into the renal vein. This vessel can usually be ligated if necessary with clips or bipolar electrocautery. In multiparous women, this vessel can be quite large and a stapler may be required. Undue traction on surrounding tissue without adequate mobilization can tear the vein. The gonadal artery may also be visualized and controlled with clips or bipolar electrocautery, although this vessel is small and typically is managed effectively even with monopolar electrocautery. The iliac vessels are at risk during dissection of the ureter or distal dissection of the descending colon.

Less common vascular injuries include trauma to the inferior mesenteric artery (most commonly in the setting of a large lower pole mass that displaces the dissection medially), the superior mesenteric artery (most commonly in the setting of a large upper pole mass that displaces the dissection medially), and the inferior mesenteric vein (when inadvertent dissection into the colonic mesentery occurs). Suspected injury to the superior mesenteric artery necessitates vascular surgery consultation because the bowel may be rendered ischemic. Inferior mesenteric artery and vein injuries can be managed by ligating the bleeding vessel. Aortic injuries are rare, usually occurring during dissection of the base of an atherosclerotic renal artery, and they may require conversion to an open surgical or hand-assistance procedure because aortic bleeding is difficult to control with laparoscopic instruments.

Any vascular injury may be increased in likelihood by poor visualization or loss of normal anatomic features. In addition, failure to keep the camera "true" with regard to the viewing angle can cause misidentification of vessels. Conversion to a hand-assisted approach or an open surgical procedure may be warranted to provide the surgeon more direct tactile feedback when other anatomic cues are lost.

On the right side the gonadal vein drains directly into the inferior vena cava. Therefore injury of the gonadal vein on the right side is more problematic than on the left side. To avoid injury, the gonadal vein should be identified inferiorly and dissection should occur lateral to the vein. Traction on the vein can easily create a pseudoaneurysm close to the insertion of the gonadal vein into the vena cava, or it can frankly tear the inferior vena cava. Unlike the adrenal vein on the left, which drains into the renal vein and is usually straightforward to manage, the short right adrenal vein drains directly into the vena cava. Especially during radical nephrectomy for a large tumor, this vessel is at risk for avulsion if it is not identified and ligated purposely. Because of the more fragile nature of venous structures, the inferior vena cava is more prone to injury than is the aorta. Predominantly sharp dissection, or only very gentle blunt dissection, should be used around the inferior vena cava. When the inferior vena cava is torn, pressure can be applied and, depending on the skill level of the surgeon, this vessel can be sutured or the procedure can be converted to an open operation. Conversion to an open procedure is recommended if the inferior vena cava is stapled as a result of misidentification.[29] If a decision is made to convert to an open surgical procedure, pressure should be maintained on the injury and all open instruments should be prepared because the loss of insufflation will uncover venous bleeding that was held in check by the pneumoperitoneum.

A critical issue during retroperitoneoscopic renal mobilization is continuous awareness of anatomic landmarks because this approach may not be intuitive to surgeons early in their experience.[30] Once the anatomic features are learned, however, this approach typically allows immediate access to the renal hilum. When approaching the hilum, however, it is easy to keep following the psoas muscle medially and to be in too posterior a location and thus dissect under the great vessels. If this situation is not recognized, it can lead to injuries of the lumbar vessels that are very

difficult to control.[31,32] To aid in maintaining landmarks, it is advisable to keep the psoas muscle as a horizon at all times. Misorienting the camera can lead to disastrous complications such as stapling across the inferior vena cava after mistaking it for the renal vein.[29] The gonadal vein and the ureter, which are often readily apparent if balloon dissection is performed in the correct plane, are useful landmarks. Once identified, these landmarks can be traced to the renal hilum. During dissection toward the hilum, ureteral, vascular, and even visceral injuries can occur during the retroperitoneal approach. Injuries are managed in a manner similar to that described with other approaches to the kidney, but the limited working space may make laparoscopic management more challenging. In some circumstances, the extraction site for the kidney can be used to manage complications with an open approach if the kidney is removed intact.[32]

Bowel Injury

To gain access to the kidney on the left side, it is necessary to mobilize the descending colon off the entire surface of the kidney. On the right side, the colon is already placed medially, and it is often necessary only to incise the peritoneum overlying the right kidney. Colon injuries related to access and thermal injury can occur in 1.5% of patients.[33] To reduce the risk of thermal injury, incision of the parietal peritoneum should be carried out far lateral to the bowel edge along the line of Toldt, with blunt mobilization of the bowel. If a thermal injury to the colon occurs, the extent of the injury can be underestimated at the time of initial inspection; this injury may become more apparent as the surgical procedure progresses. The duodenum needs to be reflected off the renal hilum on the right side, and injury can occur easily to this fragile structure. Additionally, both small bowel and large bowel are at risk during any medial dissection and during the passage of instruments into the abdomen.

For a clearly minor serosal injury, place one or more Lembert sutures to buttress the site. For full-thickness injury, consultation with a general surgeon should be considered,[34] although the current trend is to manage many of these injuries, even of the colon, with primary closure. Depending on the skill of the surgeon, nonabsorbable suture can be used to close a full-thickness injury in two layers. Alternatively, the procedure can be converted to a hand-assisted approach and the segment of bowel can be resected or repaired through the incision.[35,36] Avoidance of electrocautery near the bowel, minimized traction on the bowel, and careful instrument passage can prevent bowel injuries.

Spleen Injury

Injury to the spleen during laparoscopic left renal surgery has been reported to occur in 1.3% of cases.[33] Small thermal injuries, or tears, can often be managed by hemostatic agents and gentle pressure alone.[37,38] Splenic injuries can be very difficult to control, however, and splenectomy may be required. Moreover, delayed hemorrhage can occur from even small splenic injuries that appeared well-controlled intraoperatively.[39] Patients may present in the early postoperative period at a delayed interval following surgery, with pain, hypotension, oliguria, and/or reduced hematocrit. Bleeding may present as a subcapsular hematoma, or free intraperitoneal hemorrhage resulting in hypovolemic shock. Blood transfusion and supportive care may be adequate care in some such patients,[39] but in others splenic embolization or splenectomy may be required. Patients undergoing splenic embolization or splenectomy should be provided appropriate vaccination postoperatively.

Pleural Injury

During medial rotation of the spleen to expose the upper pole of the left kidney, the diaphragm and pleura can be injured through either cautery or sharp dissection. On the right side, injury can occur when a large liver is being reflected. Small injuries can be managed by placing a suction tip into the pleural cavity, sucking out the pleural air, and closing the diaphragm with either suture or clip. If performed at the end of the procedure, closure of the diaphragm may not be necessary if the suction catheter is removed after evacuation of intraabdominal air and removal of ports. At the conclusion of the procedure, forceful ventilation by the anesthesiologist evacuates the CO_2 from the chest cavity prior to suction removal. If the injury is large or cannot be closed adequately with sutures alone, then placement of a chest tube at the conclusion of the procedure may be warranted. If the surgeon is not comfortable with intracorporeal suturing, conversion to an open procedure may be necessary to close large defects in the pleura.[40,41]

Pancreatic Injury

The tail of the pancreas is reflected medially to expose the left renal hilum. Avoiding overly aggressive retraction or electrocautery in this area can prevent injury. If observed intraoperatively, this usually manifests as a small tear in the posterior surface of the distal pancreas. Such injuries are rarely of sufficient depth to injure the pancreatic duct, but if concern for pancreatic ductal injury exists, general surgical consultation with consideration of distal pancreatectomy is warranted. In general, when pancreatic injury is suspected, drainage is an adequate intervention. The drain can be removed following resumption of a regular diet if the drain output does not increase. Unrecognized, injury to the pancreas typically manifests as abdominal pain, nausea, vomiting, fever, and abnormal laboratory values.[42] Minor injuries typically can be managed conservatively with bowel rest, total parenteral nutrition, and percutaneous drainage of pancreatic fluid collections. In severe cases, consultation with a general surgeon may be necessary. Prolonged but eventual recovery is the expected outcome for this complication.

Hepatobiliary Injury

Thermal burns to the liver typically do not require any intraoperative management, nor do minor tears, but larger tears in the liver capsule or incision into hepatic parenchyma may require coagulation with the argon beam coagulator or placement of hemostatic agents.[39] Occasionally, the gallbladder may be injured during removal of adhesions. If this occurs, consultation with a general surgeon to remove the gallbladder is recommended.[43]

Chylous Ascites

An uncommon complication is lymphatic leakage (with formation of chylous ascites) following left-sided laparoscopic

renal surgery, owing to lymphatic disruption during mobilization and dissection of vascular structures.[44–46] This complication is most often seen when concomitant para-aortic lymph node dissection is performed. The use of bipolar devices may reduce the risk of lymphatic leakage, and large lymphatic channels can be directly cauterized or clipped. Although chylous ascites can often be managed conservatively with total parenteral nutrition or medium-chain triglyceride diets and somatostatin, surgical intervention to ligate the source of lymphatic leakage is sometimes required. Biologic adhesives have been used successfully in this setting.[47]

Procedure-specific Considerations

PARTIAL NEPHRECTOMY

Bleeding

Not unlike open partial nephrectomy, bleeding during or after surgery is the most common procedure-specific complication of partial nephrectomy. Principles for avoidance of intraoperative bleeding do not differ greatly from open partial nephrectomy (outlined in Chapter 38), but some differences in technique are worth consideration. Not unlike open partial nephrectomy, careful evaluation of tumor location, relationship to tumor vasculature, and depth of invasion is critical in planning tumor excision.

During excision of the tumor, we have generally utilized renal ischemia for those tumors with a large surface area or depth extending to or beyond the corticomedullary junction. For tumors confined to the cortex that are relatively small (<3 cm), nonclamped excision is generally feasible, particularly when utilizing robotic assistance. In several instances, intraoperative bleeding may be encountered if attempting off-clamp partial nephrectomy. It is important to fully mobilize the kidney and release the perinephric fat from the renal parenchyma well beyond the tumor, in order to avoid undue traction on the divided kidney. Such traction increases bleeding during the unclamped incision. Cutting "downhill," such that blood in the field drips away from the incision line, is also useful to limit the pooling of blood and the loss of vision. If brisk bleeding is encountered precluding vision, then arterial clamping can be conducted at any time, provided the artery has been exposed and prepared for clamp prior to renal incision. Similarly, we generally administer mannitol prior to renal incision, in the event that clamping is required.

For tumors that are resected while the artery is clamped, pulsatile intraoperative bleeding upon renal incision can indicate failure to recognize a supernumerary renal artery. In these cases, the decision to proceed with the partial nephrectomy should be based upon the surgeon's vision and the ability to ensure a negative margin. In the event that vision is obscured, one can attempt to identify the missed renal artery through use of a laparoscopic Doppler probe to allow directed dissection or, if bleeding is brisk, placement of a laparoscopic pedicle clamp through a separate stab incision. Open conversion is rarely required. In cases of good renal ischemia, the cortex appears soft as it is cut, and only minimal oozing is noted. Upon entry into the renal sinus, large venous channels may bleed, particularly on the right. In these cases, bleeding can generally be controlled by placing the hilum on stretch. If this maneuver is insufficient to tamponade the retrograde bleeding, a venous clamp can be placed.

In some cases, in which the vein and artery are clamped for excision, brisk bleeding may be encountered on renal incision. While this may indicate a missed renal artery, more commonly it may reflect venous hypertension within the kidney, secondary to some degree of arterial inflow. In these cases, removal of the vein clamp may allow the bleeding to stop sufficiently in order to complete the resection and reconstruction.

Renal reconstruction requires suture control of larger central vessels, compression of renal parenchyma, and cautery or compression control of smaller, cortical vessels. In open surgery, direct suture ligature of individual vessels, prior to division, is desirable to avoid retraction. Such a technique is not feasible in the case of laparoscopic or robotic partial nephrectomy. In laparoscopic partial nephrectomy, we have described a technique of single-pass suturing that meets all the basic tenets of reconstruction,[48] and we have subsequently adapted this for use in robotic-assisted procedures. In this technique, a suture is passed into the defect through the renal capsule (Fig. 34.2) and is

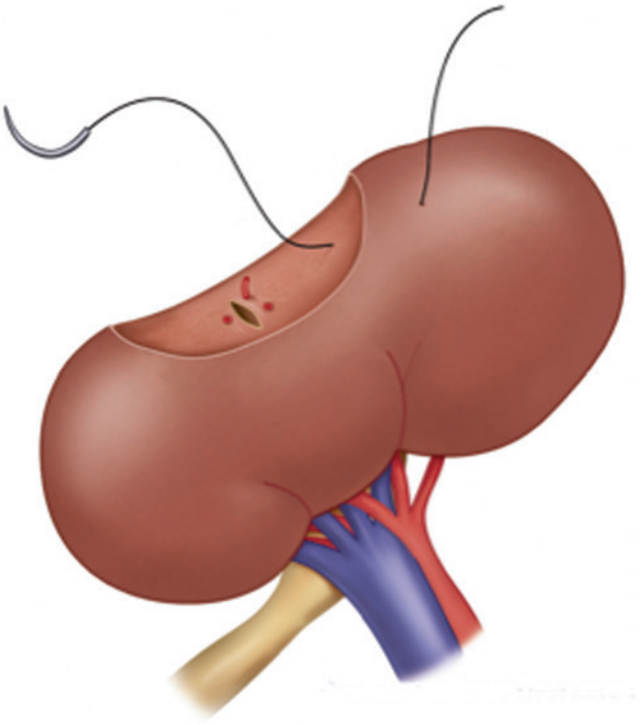


Figure 34.2 The Taneja technique of laparoscopic/robotic renorrhaphy.[48] A 2-0 Vicryl suture on an SH (small half-circle) needle is passed through the outer renal capsule approximately 2 cm from the cut edge of the resection bed into the base of the renal defect. The end of the suture is knotted and preloaded with a 5-mm locking hemoclip (Hem-o-Lok, Pilling Weck Canada LP, Markham, Ontario, Canada) to anchor the suture at the outer capsule. (Courtesy of Division of Urologic Oncology, Department of Urology, New York University Langone Medical Center, New York, 2009.)

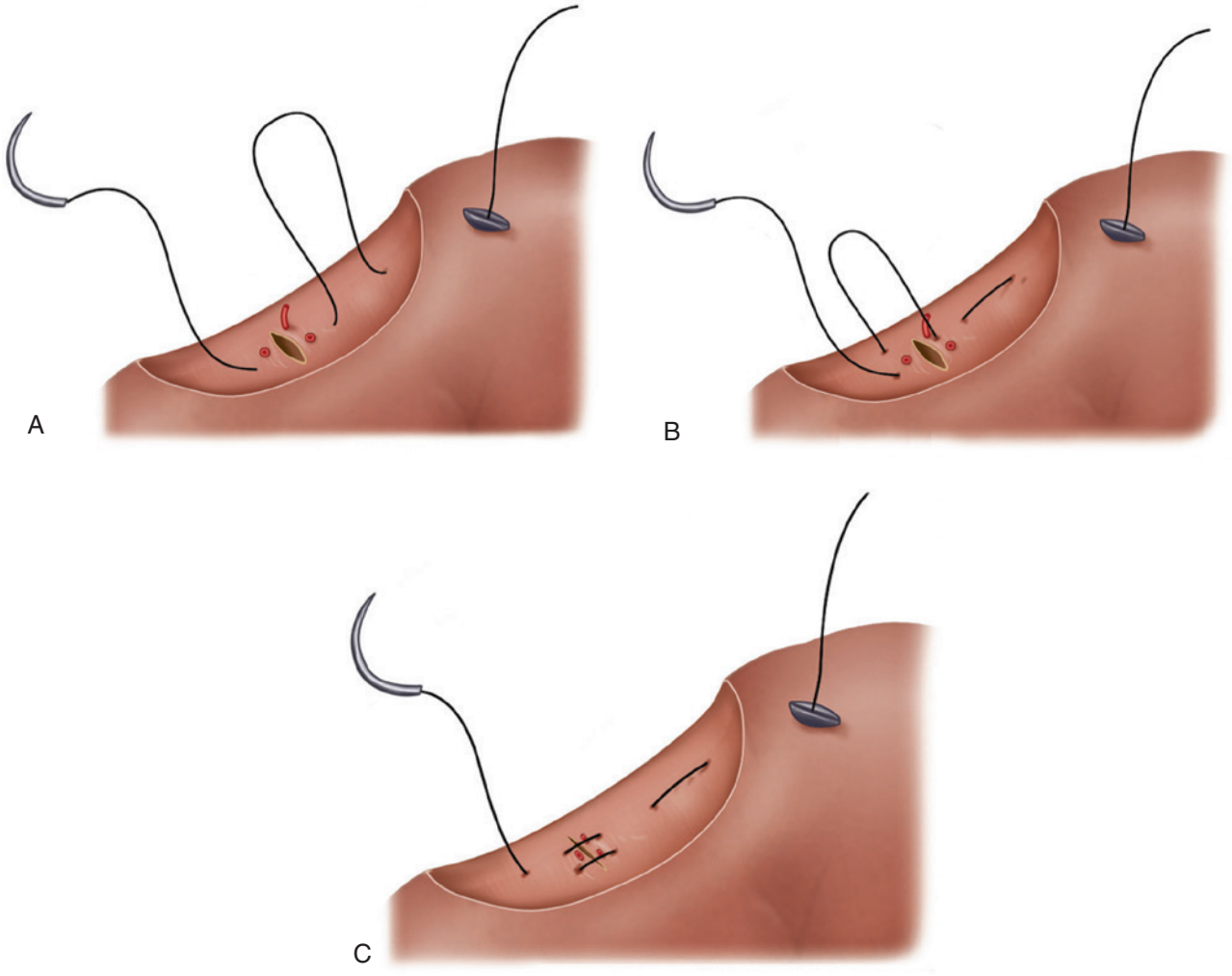


Figure 34.3 The Taneja technique of laparoscopic/robotic renorrhaphy.[48] A–C, The suture is passed in a running fashion along the deepest aspect of the renal defect, with care to incorporate collecting system opening until closure is complete. Adjacent muscular arterial branches or central venotomies are included in the suture to provide central compression, and the renal sinus is imbricated within the closure for compression. In those cases in which the collecting system is not entered, the central, deepest portion of the defect is closed with a similar running suture. (Courtesy of Division of Urologic Oncology, Department of Urology, New York University Langone Medical Center, New York, 2009.)

fixed to the surrounding capsule with a locking clip (Hemo-Lok, Pilling Weck Canada LP, Markham, Ontario, Canada). The suture is passed in a running fashion through the central portion of the defect to incorporate the collecting system and larger cut vascular channels (Fig. 34.3) and then is advanced out of the defect through the contralateral capsular edge. In doing so, the free end of the suture is secured with a clip while cinching down against the capsule (Fig. 34.4). The radial tension of the stitch pulls the central vessels into the defect rather than allowing them to retract, while compressing the surrounding renal capsule. By placing two such sutures in an X configuration, compression is directed to the center of the resection defect (Fig. 34.5). After removal of the clamp, we can add additional sutures in a similar single plane fashion across the center of the defect, as needed, to maximize compression. This is not usually required unless the defect is extremely large. To date, the technique has resulted in one episode of delayed bleeding due to pseudoaneurysm and no arteriovenous fistula (AVF) in over 500 consecutive cases.

Small vessels in the cut parenchyma that continue to ooze despite suture reconstruction can be controlled by cautery or argon beam coagulation. We have preferred use of a wet electrode (Tissue Link, Medtronic, Minneapolis, MN). Reconstruction can be bolstered by the addition of tissue adhesives or hemostatic materials, though we have not found this to be necessary in most cases. The surgeon should be aware of potential allergic reactions related to the use of bovine thrombin especially in patients who have been previously exposed to this product during other surgical procedures (commonly cardiac surgery). An allergic reaction can produce coagulopathy that can be life threatening to the patient. The surgeon must have the patient's complete surgical history before these products are used and, if necessary, must review prior operative reports to determine whether the use of the hemostatic agents could place the patient at risk.[49,50]

On rare occasions, postoperative bleeding following partial nephrectomy can present any time up to 60 days following partial nephrectomy. This is most commonly due

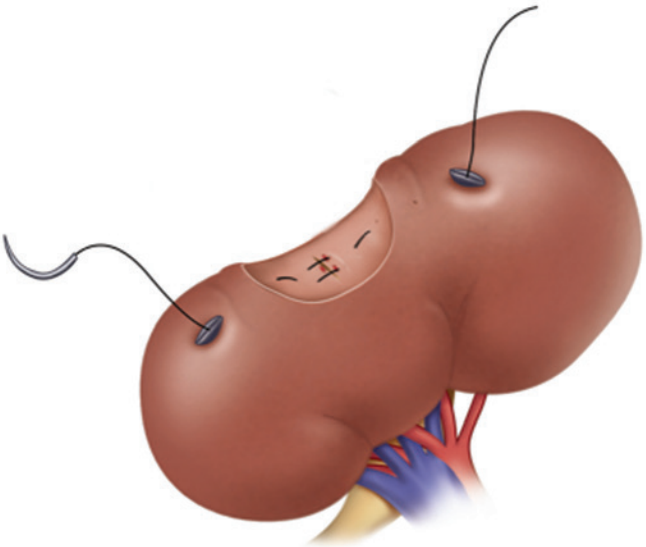


Figure 34.4 The Taneja technique of laparoscopic/robotic renorrhaphy.[48] While the surgeon holds the leading edge of the suture on tension, the needle is passed out of the resection bed through the outer renal capsule opposite the site of entry. A locking hemoclip (Hem-o-lok, Pilling Weck Canada LP, Markham, Ontario, Canada) is used to cinch the suture, compress the defect, and lock the suture in place. Compression of the resection defect is achieved by cinching the suture ends in the direction of the central portion of the defect. (Courtesy of Division of Urologic Oncology, Department of Urology, New York University Langone Medical Center, New York, 2009.)

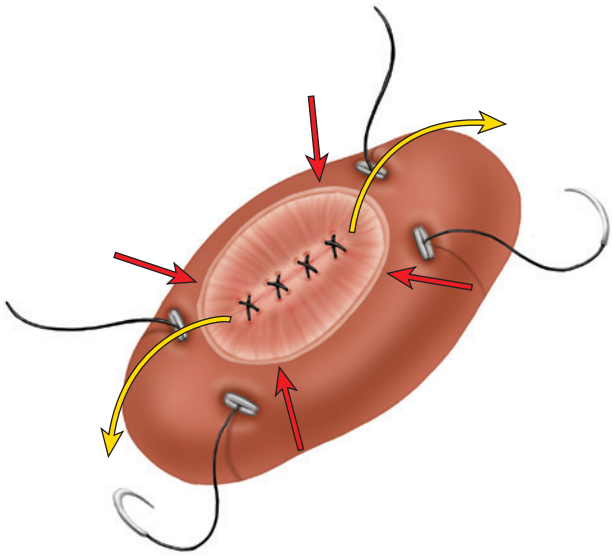


Figure 34.5 The Taneja technique of laparoscopic/robotic renorrhaphy.[48] By placing two such sutures in an X configuration, compression is directed to the center of the resection defect. The radial tension of the stitches pulls the central vessels into the defect (yellow curved arrows) rather than allowing them to retract, while compressing the surrounding renal capsule (red arrows).

to formation of a pseudoaneurysm that breaks into the collecting system or bursts. Similarly, an AVF can do the same, but often presents earlier in the postoperative course. It is our experience that delayed bleeding due to pseudoaneurysm or AVF is far more common with minimally invasive procedures than with open, and this may reflect less precise

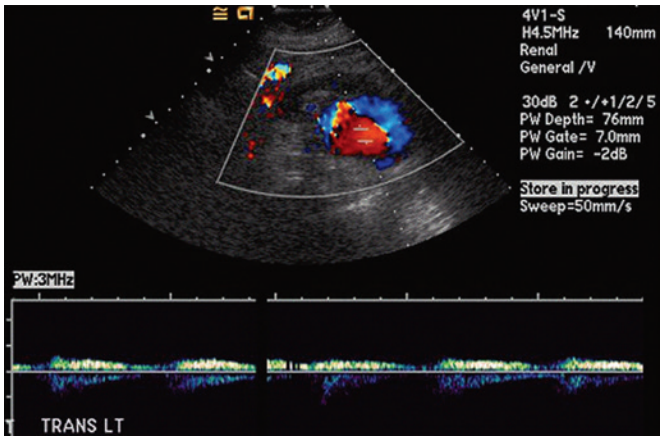


Figure 34.6 Duplex ultrasonography demonstrating the "yin-yang" sign of turbulent mixing of arterial and venous blood following laparoscopic partial nephrectomy. (Courtesy of Michael Stifelman, MD.)

suturing techniques. Generally, patients may present with sudden gross hematuria. Retroperitoneal bleeding, resulting in hemodynamic instability, is possible but far less common. At presentation, the surgeon should have high suspicion for pseudoaneurysm or AVF and proceed to angiography. Although duplex ultrasound (Fig. 34.6) or CT may identify the fistula, angiography can identify the fistula and allow for management through selective embolization in the same setting (Figs. 34.7A–C).[51]

Urine Leak

Urine leak has been reported in 3– 5% of patients undergoing laparoscopic partial nephrectomy.[52–55] Urine leak was noted in 0.78% of patients who underwent robotic-assisted partial nephrectomy in one large multi-institutional study.[56] Management of urine leak is discussed in detail in Chapters 13 and 38, and the management of urine leak following laparoscopic or robotic-assisted partial nephrectomy does not differ greatly from that of an open partial nephrectomy. As laparoscopic procedures are more often performed through a transperitoneal exposure, the risk of urinary ascites and secondary ileus may be greater. Variables associated with urine leak include: tumor size, hilar location, operative time, warm ischemia time, and pelvicalyceal repair.[56]

If the collecting system is entered, the surgeon should leave a closed drain near the tumor resection bed and a Foley catheter in the bladder during the initial postoperative period. If no drainage is noted from the drain, the catheter is removed 1–2 days postoperatively, and the drain is monitored before removal. We routinely check creatinine level from the drain prior to removal.

Most urine leaks following laparoscopic partial nephrectomy present in the very early postoperative period with increased drain output, which on chemical testing is found to be most consistent with urine. Upon demonstration of urine leak, ultrasound or cross-sectional imaging should be performed to rule out undrained urine collections, hydronephrosis, and concern for ureteral injury. In the absence of these findings, the patient is generally sent home with the drain to wait for resolution of the leak. The drain can be left in place for several weeks to allow healing of the fistula, which generally occurs by scarring down the perirenal

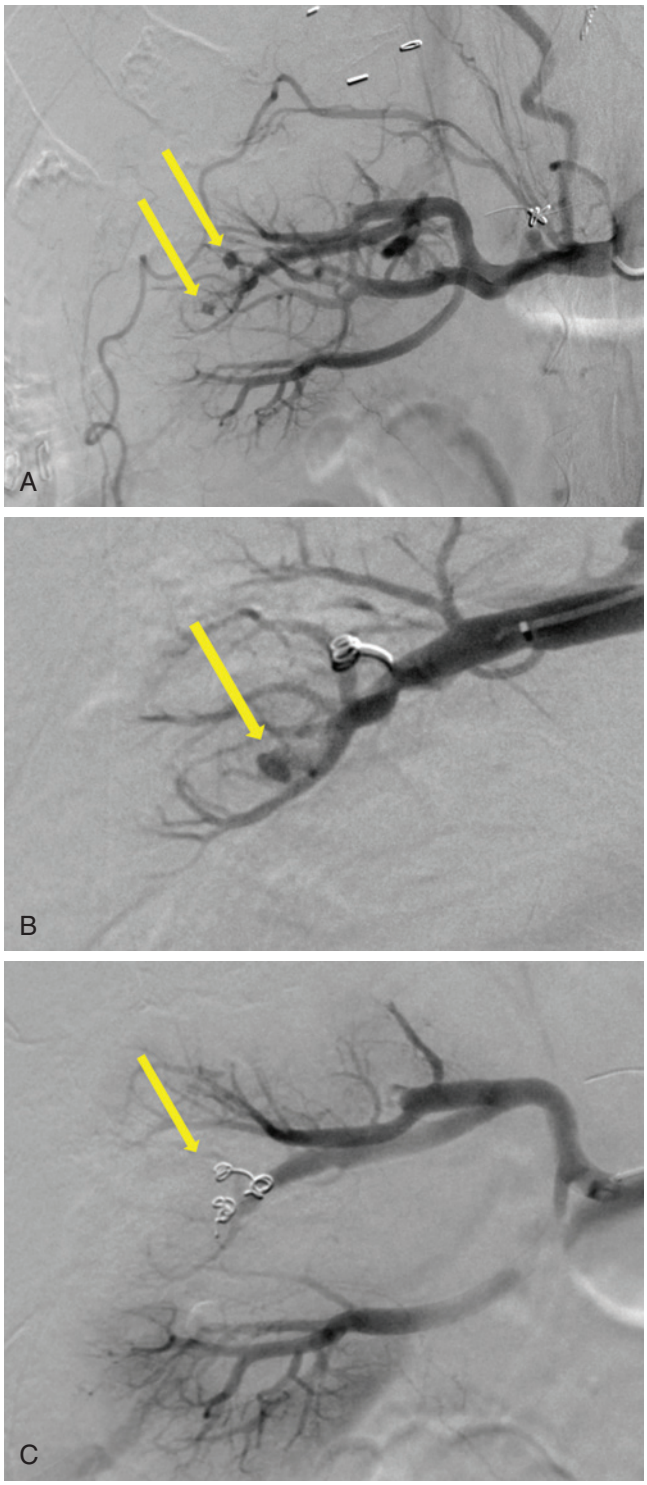


Figure 34.7 Angiography in a 75-year-old man presenting with gross hematuria, 10 days after robotic-assisted laparoscopic partial nephrectomy for three right renal tumors. A midpole branch of the posterior segmental artery demonstrates a 3-mm pseudoaneurysm and an adjacent arteriocalyceal fistula (yellow arrows, panel A). Following selective embolization of that branch, an adjacent arterial branch demonstrates an arteriovenous fistula (yellow arrow, panel B). Following selective embolization of both branches, no further bleeding sites are noted (panel C). (Courtesy of Michael Stifelman, MD.)

space around the drain. As drain outputs decline, the drain can be advanced out slowly to allow the tract to scar down and close the leak. It has not been our general practice to place ureteral stents or nephrostomy, unless there is hydronephrosis due to obstruction present in the operated kidney. On occasion, large lower pole leaks resulting in pooling of urine around the proximal ureter or ureteropelvic junction may warrant stent or nephrostomy drainage due to the risk of periureteral fibrosis and secondary obstruction with perpetuation of the leak. Leaks that persist at high volume (>500 mL/day) may indicate anatomic abnormality or infarction of tissue, and in these cases, placement of stent or percutaneous nephrostomy may be considered. Occasionally, persistent urinomas require percutaneous drainage under ultrasound or CT guidance.[55,57]

Delayed presentation of leak is less common, but since most patients appear well after minimally invasive surgery, the surgeon should be careful to rule out the presence of urinoma in follow-up. We have employed postoperative ultrasound to rule out urinoma in patients recovering from partial nephrectomy, but this is extremely low yield when used empirically. Additionally, it is not unreasonable for uncomplicated urinomas away from the ureter, in the absence of infection or obstruction, to be observed. They will often resolve on their own over time or become small diverticuli off the collecting system.

Renal Function

Prolonged renal ischemia can result in postoperative acute tubular necrosis (ATN) and acute failure of the kidney. These complications are especially problematic if the partial nephrectomy is performed for absolute indications (solitary kidney, poor renal function). Because suturing is required for deeper resections, the likelihood of prolonged ischemia times during minimally invasive partial nephrectomy is greater in the setting of deep tumors. Given the considerable learning curve of sutured bolster application for minimally invasive partial nephrectomy, it is recommended that early in a surgeon's experience the procedure should be limited to small exophytic tumors to allow the surgeon to gain comfort with the steps of the procedure.[58]

Most minimally invasive partial nephrectomies should reasonably be completed with a clamp time of ≤30–45 minutes. Although a warm ischemia time of <60 minutes has been reported to be safe, if a longer ischemia time is anticipated because of the complexity of the procedure, several maneuvers may assist in limiting ischemic injury. We routinely give 12.5 g of mannitol before clamping the renal hilum, followed by an additional 12.5 g when the hilum is unclamped. However, the influence of mannitol on renal function recovery remains controversial.[59] Additional maneuvers to limit global renal ischemia include "zero ischemia" in which tumor-specific clamping of the artery/vein occurs, coupled with carefully calibrated and timed intraoperative reduction of blood pressure,[60] selective/segmental arterial clamping without main renal artery clamping,[61] early arterial unclamping,[62] and off-clamp partial nephrectomy.[63] The benefits of limited arterial clamping appears to be attenuated by 3 months' follow-up.[64,65] In addition, intracorporeal cooling techniques have been introduced to facilitate cold ischemia during robotic partial nephrectomy.[66]

We have generally felt that most of these maneuvers are unnecessary, and we have been able to perform partial nephrectomy by laparoscopic robotic-assisted technique in the majority of patients with deep or complex tumors, solitary kidney, multifocality, and preexisting renal disease. In cases at high risk for postoperative ATN, off-clamp partial nephrectomy is desirable whenever feasible.

Repeat robotic partial nephrectomy poses challenges and complications. Repeat surgery is technically challenging with some studies reporting an association with increased blood loss and postsurgical length of stay as well as increased rates of urine leak.[67] Repeat robotic partial nephrectomy can be safely and effectively performed in patients presenting with local recurrence after primary nephron-sparing surgery for kidney cancer.[68]

Renal malignancies are often diagnosed at an older age, and although the elderly have more comorbidity and often lower eGFR, it appears that elderly patients undergoing robotic partial nephrectomy do not have increased risk of perioperative complications compared to their younger counterparts.[69,70] Hospital readmission within 30 days of surgery after robotic partial nephrectomy occurs at a rate of about 4.5%, associated most commonly with patient comorbidity.[71] Postoperative bleeding is the most common driver of readmissions, occurring in more than 25% of readmitted patients.[71]

Donor Nephrectomy

Laparoscopy is the preferred management for donor nephrectomy and may be responsible in large part for the increase in the number of living related donors for renal transplantation.[72] In several large series, major complications were reported in 4–6% of patients.[73–75] Although these renal units are anatomically normal, the need to remove a functional organ with adequate ureteral and vascular length for anastomosis in the recipient, while maintaining safety for the donor, leaves a small margin for complications in this procedure.

Complications most likely to affect the quality of the graft relate to vascular injury. The left kidney is the most frequently removed from the donor in most institutions. Ligation of the small tributaries of the renal vein without use of clips can reduce the risk of staple misfire due to an entangled clip. In a series of eight stapler malfunctions involving the renal vein during laparoscopic nephrectomy, the most common cause was stapling over a clip.[76] In a reported donor nephrectomy series, six of 738 cases resulted in vascular injury caused by staple misfiring or malfunction and necessitating conversion to an open surgical procedure.[51]

Other vascular injuries reported during laparoscopic donor nephrectomy include laceration of the renal vessels during dissection, clip dislodgment from the renal artery stump, and vascular tears at the junction of the renal vessels and the aorta or inferior vena cava.[77] A significant number of reports of slippage of Hem-o-lok clips (Pilling Weck Canada LP, Markham, Ontario, Canada) off the renal artery during laparoscopic donor nephrectomy caused the U.S. Food and Drug Administration to prohibit the use of these clips to control the renal artery during this procedure.[78] This prohibition is limited to laparoscopic donor nephrectomy, and these clips can still be used at the surgeon's discretion during simple or radical nephrectomy. This decision should be based on the length of remaining arterial stump for secure clip placement.

Several aspects of laparoscopic donor nephrectomy can compromise the function of the graft in the recipient. Ureteral injury can result in inadequate length for ureteroneocystotomy. To ensure adequate distal ureteral blood supply to prevent anastomotic strictures, many urologists preserve the gonadal vein along with the ureter during harvesting.[79] Delayed graft function is likely related to many factors, including prolonged warm ischemia time and vasospasm in the graft. Moreover, delayed graft function is related to overall graft survival.[79] Hand-assistance procedures may minimize warm ischemia time,[80] and these procedures may be safer than bag entrapment as for intact extraction after standard laparoscopy. Several reported cases of renal laceration and hematoma were related to injury from specimen entrapment.[81] "Resting" of the kidney and the use of diuretics and papaverine minimize vasospasm in the kidney and reduce the incidence of delayed graft function.[55] Up to 2% of patients report testicular pain, leg numbness, or other scrotal problems following laparoscopic donor nephrectomy related to gonadal vein ligation (in young patients) and possible injury to the ilioinguinal or genitofemoral nerves.[82]

Simple Nephrectomy

The term *simple nephrectomy* encompasses a large number of benign indications. Laparoscopic nephrectomy has been reported for xanthogranulomatous pyelonephritis, other infectious causes (tuberculosis), polycystic renal disease, and nonfunctioning (chronic hydronephrosis, failed pyeloplasty, reflux nephropathy) or atrophic kidneys. In a meta-analysis of laparoscopic renal complications, simple nephrectomy had the highest incidence of conversion to an open procedure, at 3.7%.[33] The predominant causes of complications associated with this procedure are inflammation distorting normal tissue planes and the lack of working space resulting from enlarged and distorted renal units.

The colon may be at more risk of injury than in other laparoscopic renal surgical procedures because inflammation makes mobilization difficult. A complete mechanical bowel preparation is indicated in this population, in whom the risk of injury approaches 1%.[83–87] A common pitfall during colon mobilization in laparoscopic simple nephrectomy is dissection into the colonic mesentery. A through-and-through dissection can occur easily without recognition. This dissection increases the likelihood of vascular injury, including injury to the mesenteric and contralateral renal vessels.[29] A clue to this incorrect dissection is the finding of vessels directed toward the colon. A large mesenteric opening does not require closure. Small openings may require closure to prevent the possibility of internal hernia.

If colon injury does occur, the extent of the injury should guide management. Treatment can range from reinspection of the area at the conclusion of the procedure for serosal injuries to laparoscopic repair or resection of full-thickness tears. Depending on experience and access to intraoperative consultation, laparoscopic management may be possible, or this injury may require conversion to an open procedure for repair and completion of the operation.

A second potential problem encountered with simple nephrectomy caused by lack of tissue planes is difficulty with renal hilar dissection and management. Inflammatory processes such as xanthogranulomatous pyelonephritis or chronic hydronephrosis resulting from nephrolithiasis may create significant perihilar inflammation or adenopathy that prevents successful isolation of the renal artery and vein. Although we prefer to ligate the renal artery and vein separately, in this circumstance it is often best to place a single clip on the renal artery (to stop blood flow) and then use a vascular laparoscopic stapler to control the hilum distal to the clip. Although not recommended as a routine measure, a stapler can be used to ligate the entire hilum en bloc with little risk of arteriovenous fistula.[88,89]

The real risk in using a stapler to ligate the entire hilum en bloc is not arteriovenous fistula formation, but rather the possibility that the stapler will misfire because too much tissue remains around the hilum for the device to close adequately. Enough dissection needs to be performed to thin the tissue bundle. If that is not possible, consideration of conversion to a hand-assistance procedure or an open operation is warranted, given that failure to control the hilum can be life threatening. If the stapler does fail, the hilum en bloc can often be clamped again for temporary hemostasis. If feasible, a second trocar can be placed adjacent to the one with the stapler and a second stapler can be introduced more proximally on the vessels. The risk here is injury to a great vessel if the surgeon is disoriented.[85]

Because simple nephrectomy is not an oncologic procedure, the tendency exists to dissect close to the kidney. Although the space within Gerota's fascia or a subcapsular plane may provide the best mobilization and dissection of the kidney, this often places the surgeon very close to the renal sinus, where multiple arterial and venous branches may be encountered and vascular control may be more difficult. Identification of the gonadal vein with dissection of this vessel toward the renal hilum typically places the surgeon proximal enough on the renal artery and vein to avoid managing multiple branches.

A common problem encountered intraoperatively is failure to progress. Although this is not a complication, awareness of lack of progression during the case and conversion to hand-assistance procedures or an open operation can prevent the risks associated with prolonged operative time. Failure to progress often results from difficulty with mobilization of the kidney, owing to chronic infection, previous nephrostomy tube, and prior operation on the kidney or ureter, for example.[85–87]

The major risks in patients following laparoscopic simple nephrectomy are infection and abscess formation, especially in patients with xanthogranulomatous pyelonephritis. Before the procedure, obtain a urine culture from the patient and treat any infection appropriately. In such cases, it may be advantageous to leave a drain in place following the procedure. In cases of infection caused by chronic reflux nephropathy, ligate the ureteral stump with a clip. Despite preventive measures, many patients managed by simple nephrectomy have an infectious complication. Medical comorbidities such as diabetes can increase this risk.

Conclusions

Minimally invasive renal surgery when applied to the appropriate candidate and performed with good clinical judgement may allow for low complication rates, ultimately improving clinical outcomes for patients. An adequate technical skillset and an understanding of the relevant anatomy, and anatomic variations, as well as adherence to fundamental techniques, can avoid a number of common complications. Early recognition and management of complications, when arising, is critical in preserving good outcomes for the patient.

References

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Chapter 34 Questions

1. A 45-year-old male undergoes a left robotic-assisted laparoscopic partial nephrectomy for a 3-cm left renal mass. The renal artery and vein are clamped. Upon incision of the renal parenchyma, steady, nonpulsatile bleeding is noted from the tissue, precluding vision of the resection margin. The next maneuver is to:
   a. Attempt to suture bleeding points
   b. Reclamp the renal artery
   c. Unclamp the renal vein
   d. Identify additional renal arteries
   e. Proceed with nephrectomy

2. A 62-year-old woman is scheduled for a left nephrectomy, and she desires a minimally invasive approach. She has had a previous left colectomy and colostomy for perforated diverticulitus, followed by colostomy take down. The most reasonable surgical approach is:
   a. Transperitoneal laparoscopic
   b. Robotic-assisted transperitoneal laparoscopic
   c. Retroperitoneal laparoscopic
   d. Open transperitoneal
   e. Open retroperitoneal

3. A 63-year-old man presents with a 9-cm right renal mass encroaching upon the renal hilum. During surgery the renal artery is effaced by the tumor and local lymphadenopathy, precluding its identification. Significant venous bleeding is noted from the hilar region. The next step is to:
   a. Place a pedicle clamp
   b. Mass divide the pedicle with a stapler
   c. Divide the renal vein to expose the artery
   d. Pack the area, close, and proceed with angioembolization
   e. Identify the right renal artery medial to the vena cava

4. A 56-year-old female develops bright red painless gross hematuria 15 days after a left laparoscopic partial nephrectomy for a lower pole renal mass. The hematuria subsides 10 hours later, and she presents to the office the following day. The next step is:
   a. Urine culture
   b. Cystoscopy
   c. Retrograde pyelogram
   d. Duplex ultrasound
   e. Angiogram, selective angioembolization

5. During mobilization of the left kidney for laparoscopic nephrectomy, an inadvertent 1-cm injury to the posterior capsule of the distal pancreas is noted. There is no evidence of fluid leaking from the injury, and it appears to have a depth of <1 cm. The next step is to:
   a. Abort nephrectomy and leave a drain
   b. Complete nephrectomy and leave a drain
   c. Repair injury with interrupted absorbable suture
   d. Abort nephrectomy and perform distal pancreatectomy
   e. Complete nephrectomy with en bloc distal pancreatectomy

6. A 58-year-old man with a BMI of 33.8 undergoes a left laparoscopic nephrectomy for a 7-cm upper pole renal tumor. He has a previous history of colon cancer, requiring left colectomy. Surgery is prolonged due to adhesions, tumor size, and obesity. In the recovery room, he complains of unremitting pain in his left lower extremity, radiating from the hip to the upper thigh. On exam, the right buttock is tender, but not swollen, and neurologic exam and lower extremity pulses are normal. The most likely diagnosis is:
   a. Lumbar disc herniation
   b. Sciatic nerve compression
   c. Deep vein thrombosis
   d. Gluteal compartment syndrome
   e. Hematoma

7. The use of locking clips (Hem-o-lok) for control of the renal artery(ies) is prohibited by the Food and Drug Administration during the performance of:
   a. Reoperative renal surgery
   b. Radical nephrectomy
   c. Simple nephrectomy
   d. Donor nephrectomy
   e. Cadaveric nephrectomy

8. A primary advantage of the retroperitoneal laparoscopic approach is:
   a. Large working space
   b. Early identification of the renal artery
   c. Reduced risk of bleeding complications
   d. No risk of bowel injury
   e. Reduced subcutaneous emphysema

9. During laparoscopic transperitoneal simple nephrectomy for xanthogranulomatous pyelonephritis, a good landmark to aid in identifying the renal hilum is the:
   a. Gonadal vein
   b. Adrenal gland
   c. Great vessels
   d. Renal pelvis
   e. Ureter

10. Following an uncomplicated robotic-assisted partial nephrectomy, increased drain output is noted on postoperative day 3. Drainage creatinine is measured at 32 ng/dL. In this patient, one should consider stent placement if:
    a. Cross-sectional imaging confirms a urinoma
    b. Drain outputs exceed 500 mL/day
    c. Imaging demonstrates hydronephrosis
    d. The leak is from the upper pole
    e. Multiple tumors were resected

Case Study 1

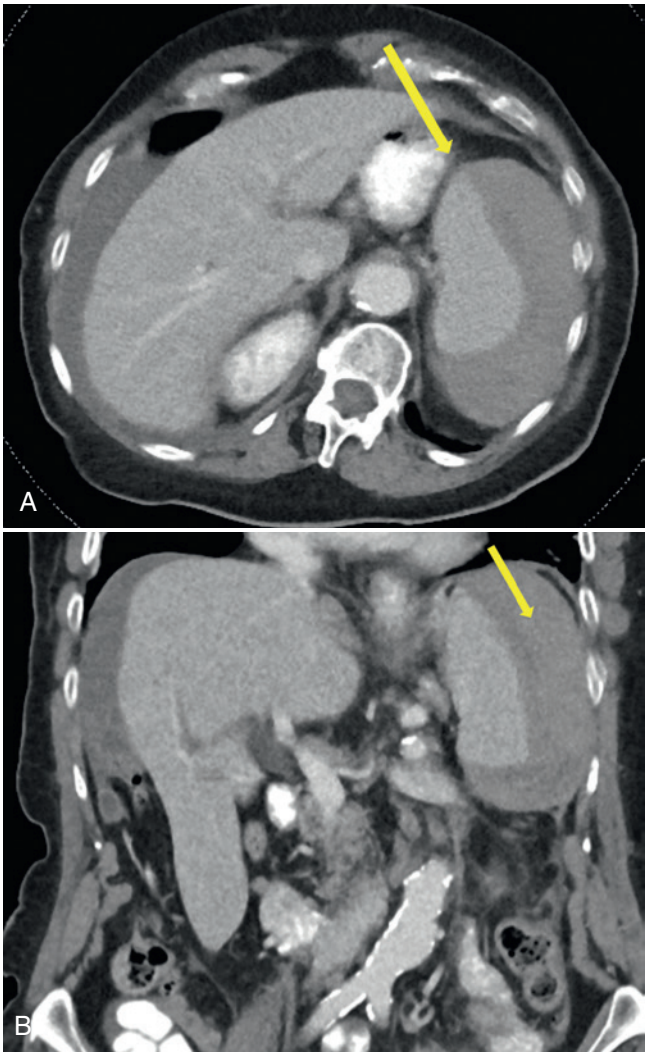
A 74-year-old woman underwent an uncomplicated left robotic-assisted partial nephrectomy for an upper pole renal mass. She was discharged home 1 day after surgery, feeling well. On the 14th postoperative day, after coughing, she slowly starts to develop left upper quadrant and flank pain. She denies hematuria. On evaluation, her exam is

unremarkable, with the exception of mild left upper quadrant/flank tenderness. She has no hematuria. Her hemoglobin is 12.3 g/dL.

1. The next step is:
   a. Observation, antacids, analgesics
   b. Contrast chest CT
   c. Abdominal CT
   d. Renal duplex
   e. Angiography, selective embolization

A CT scan is performed (Case Fig. 34.1) demonstrating a large subcapsular hematoma of the spleen (yellow arrows). Following hydration, the hemoglobin is 8.9 g/dL. Over the next 6 hours, following resuscitation, the hemoglobin declines to 7.8 g/dL.

2. If the patient were to undergo a splenectomy, she would require:
   a. Platelet transfusions
   b. Chronic suppressive antibiotics
   c. Pneumococcal vaccine
   d. Immunostimulatory agents
   e. Protective clothing



Case Figure 34.1

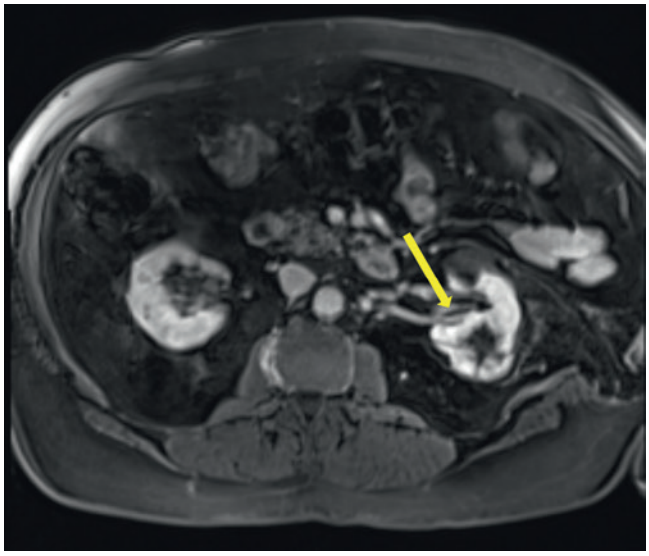
3. If continued bleeding is noted, the optimal treatment would be:
   a. Systemic hemostatic agents, supportive care
   b. Spleen angioembolization
   c. Percutaneous drainage of hematoma
   d. Re-exploration with splenorraphy
   e. Re-exploration with splenectomy

Case Study 2

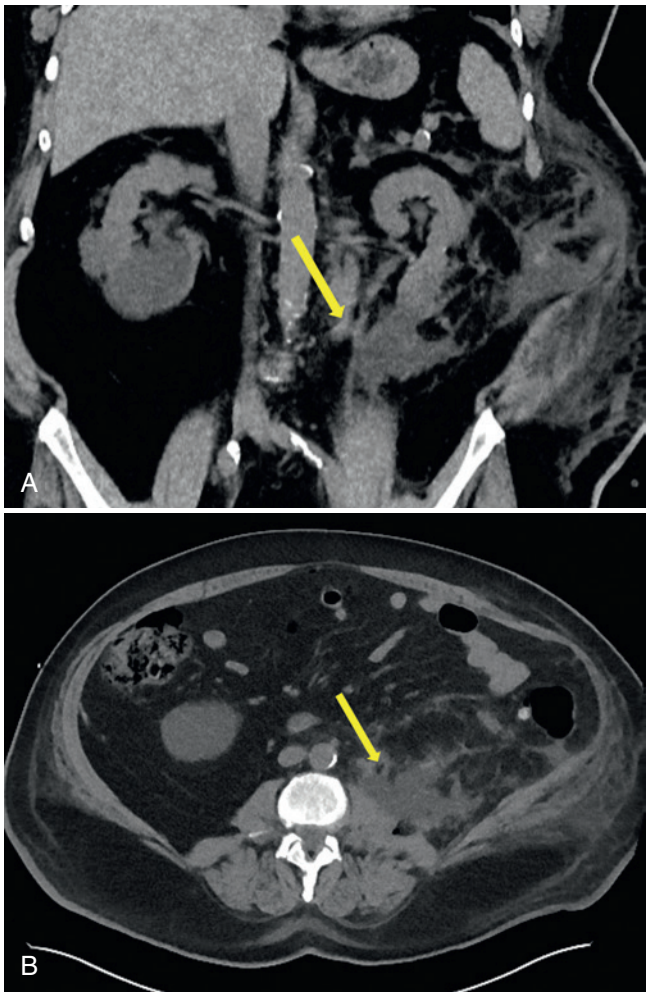
A 67-year-old male presents with a 4.5-cm left lower pole renal mass (Case Fig. 34.2) and a history of chronic kidney disease. He has undergone a previous open partial nephrectomy through a left flank incision for a renal cell carcinoma located in the midpole, 3 years earlier. A robotic-assisted partial nephrectomy is performed, and, at the time of surgery, severe fibrosis and scarring is identified around the lower pole, renal hilum, and posterior renal plane. With difficulty, the ureter is released from the scar and retracted medially to allow a partial nephrectomy to be performed. The collecting system is visibly entered and repaired. Following surgery, his baseline serum creatinine rises from 1.5 ng/dL to 2.7 ng/dL over 3 days. His drain output is elevated to 150–200 mL per 8-hour shift. Drain creatinine level is 28 ng/dL. He has no fever, and his white blood cell count is within normal limits.

1. The next step is:
   a. Continued observation
   b. Advance the drain
   c. Cross-sectional imaging
   d. Place stent
   e. Place nephrostomy

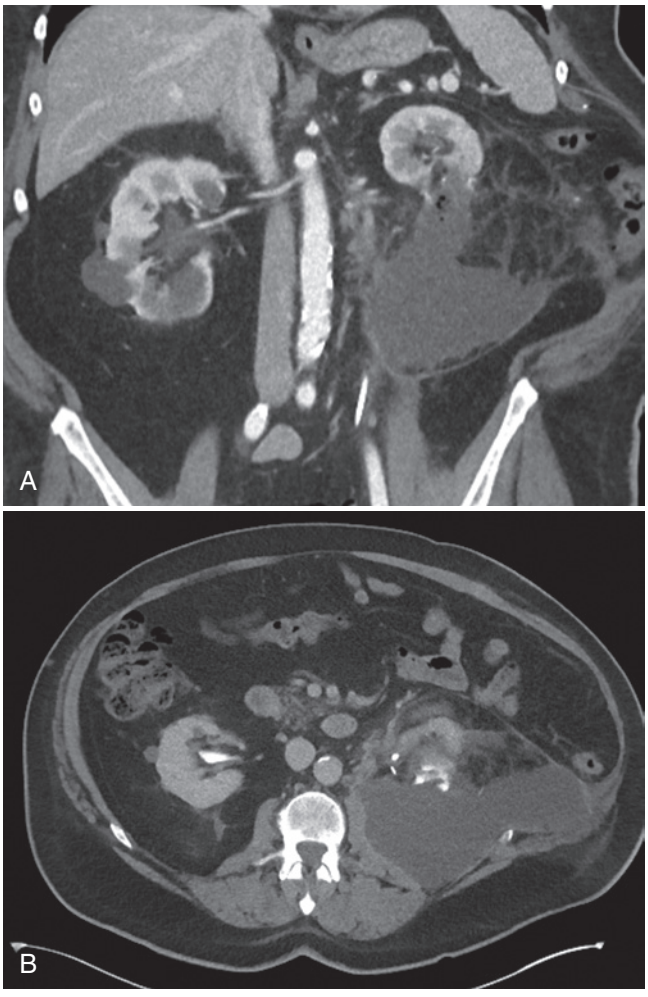
A CT scan without contrast is performed (Case Fig. 34.3), demonstrating a fluid collection (Case Fig. 34.3A, yellow arrow) surrounding the lower pole and proximal ureter (Case Fig. 34.3B, yellow arrow). There is minimal hydronephrosis. The position of the leak cannot definitively be determined.



Case Figure 34.2



Case Figure 34.3



Case Figure 34.4

2. The next step is:
   a. Continued observation
   b. Retrograde pyelogram and possible stent
   c. Nephrostomy placement
   d. Remove suction from drain
   e. Re-exploration for repair or nephrectomy

A retrograde pyelogram demonstrates patency of the ureter, with considerable extravasation from the lower pole collecting system (Case Fig. 34.3). A stent is placed, along with a urethral catheter, and the patient's drain output subsides greatly over the next 24 hours. He is discharged home with drain outputs of 20 mL per 8-hour shift. He returns 2 weeks later with the catheter removed. His drain is no longer putting out any fluid. He is feeling well. A CT urogram is performed prior to drain removal (Case Fig. 34.4) as shown.

3. The next step is:
   a. Replace urethral catheter
   b. Replace urethral catheter, percutaneous drain placement
   c. Replace urethral catheter, percutaneous nephrostomy placement
   d. Replace urethral catheter, percutaneous drain placement, and sclerosis
   e. Replace urethral catheter, open drainage, and nephrectomy

Answers

1. **c.** Bleeding upon incision of the renal parenchyma, with the hilar vessels clamped generally indicates accessory renal arterial supply that was not identified during hilar exposure. While identification of the additional arterial supply may be warranted, steady bleeding as described may indicate venous hypertension due to arterial inflow, with obstructed venous outflow. In this case, initial release of the venous clamp is a reasonable first maneuver as it will likely reduce bleeding. In the event that bleeding continues, an attempt to identify accessory renal arterial supply, through use of a laparoscopic Doppler probe, or placement of a pedicle clamp is reasonable.
2. **e.** While any of the surgical approaches is feasible, the most difficult, due to previous intraabdominal surgery and infection, is the transperitoneal laparoscopic or open approach. In this case, the use of robotic assistance would not reduce the degree of difficulty, due to adhesions precluding the development of an adequate working space and the presence of pericolic fibrosis. While this patient desires a minimally invasive approach, and laparoscopy by retroperitoneal approach could be considered, it is not the optimal approach as retroperitoneal adhesion is likely present

and would make balloon insufflation of the retroperitoneum risky given the potential for vascular or bowel injury. In this case, an open retroperitoneal approach would be most prudent.

3. **e.** While preoperative angioembolization is helpful in cases of large renal tumors encroaching upon the renal artery, intraoperative identification of the problem precludes such an approach due to ongoing bleeding. In these cases, division of the vein would only increase bleeding significantly, while any attempt at mass ligation of the pedicle would risk vascular injury due to the blind nature of the maneuver. In this case, the ideal approach would be to identify the renal artery away from the affected region of the operative field, in the interaortocaval groove.
4. **e.** The presentation of sudden onset gross hematuria in the patient recovering from partial nephrectomy should prompt a suspicion of pseudoaneurysm or arteriovenous fistula. In this case, the patient has stopped bleeding, but is at risk of bleeding again. In the absence of symptoms, there should be low suspicion for cystitis or renal stone disease. While duplex ultrasound may identify an arteriovenous fistula, the patient is at high risk for re-bleed and potential for significant blood loss. Angiography is the definitive test to rule out a source of bleeding and allow for corrective intervention.
5. **b.** In this case, the location and size of the injury would indicate that there is very little risk of injury to the pancreatic duct. As such, drainage is an adequate management strategy for this injury, and pancreatectomy is not warranted. There is no reason to abort the nephrectomy in this case.
6. **d.** In this patient, his obesity and prolonged surgery put him at risk of gluteal compartment syndrome and secondary rhabdomyolysis as a result of prolonged compression of the right gluteal compartment in the right lateral decubitus position. Prompt evaluation with compartment pressures, urinary myoglobin testing, and measurement of serum CPK is warranted, but may not identify the diagnosis at this early point in his clinical presentation. As such, early consideration of fasciotomy to minimize muscle necrosis is warranted.
7. **d.** A significant number of reports of slippage of Hemo-lok clips off the renal artery during laparoscopic donor nephrectomy caused the U.S. Food and Drug Administration to prohibit the use of these clips to control the renal artery during this procedure. This prohibition is limited to laparoscopic donor nephrectomy, and these clips can still be used at the surgeon's discretion during simple or radical nephrectomy. This decision should be based on the length of remaining arterial stump for secure clip placement.
8. **b.** Retroperitoneal laparoscopic exposure of the kidney allows for early identification of the renal artery, but does not reduce the risk of vascular complications due to the risk of misorientation within a reduced working space and inadvertent injury to the great vessels or renal hilum. While bowel is not present in the field, thermal transmission to the peritoneum risks inadvertent, unrecognized bowel injury. Insufflation of the retroperitoneum, particularly in a thin person, can lead to increased risk of subcutaneous emphysema, pneumomediastinum, and pneumothorax.
9. **a.** Because simple nephrectomy is not an oncologic procedure, the tendency exists to dissect close to the kidney. Although the space within Gerota's fascia or a subcapsular plane may provide the best mobilization and dissection of the kidney, this often places the surgeon very close to the renal sinus, where multiple arterial and venous branches may be encountered and vascular control may be more difficult. Identification of the gonadal vein with dissection of this vessel toward the renal hilum typically places the surgeon proximal enough on the renal artery and vein to avoid managing multiple branches.
10. **c.** In most patients with early urine leak following partial nephrectomy, stent or nephrostomy placement is not needed in the absence of obstruction. Cross-sectional imaging should be performed to rule out urinoma and hydronephrosis. The presence of urinoma should prompt additional extrarenal drainage, and the presence of hydronephrosis should prompt renal drainage. Most early leaks should resolve if well controlled with drain placement, even in the setting of high outputs or complex resections.

CASE STUDY 1

1. **c.** In this patient, the suspicion for renal arteriovenous fistula should be low, given the absence of hematuria and the primary presentation of pain. As such, renal duplex and arteriogram would not be the likely, best first test. While a retroperitoneal hematoma is a feasible cause for left upper quadrant pain and tenderness, the normal hemoglobin does not support this. In this case, a CT scan of the abdomen will aid in determining if a hematoma is present and if a secondary intra-abdominal process is ongoing. As such, in this case, it is the most informative first test.
2. **c.** Patients undergoing splenectomy, either electively or due to incidental injury, are at risk for pneumococcal infections, and it is generally advised they should have a pneumococcal vaccine. Other immunostimulatory, or hematologic, therapy is not needed.
3. **b.** Subcapsular hematoma of the spleen may be a self-remitting process. In this case, continued observation to determine if the bleeding subsides would be a reasonable approach if the patient remains hemodynamically stable. If continued bleeding is noted, or the patient becomes progressively unstable, angioembolization is a reasonable first approach prior to splenectomy with reasonable success rates. If bleeding progresses despite embolization efforts, then splenectomy is likely warranted. Efforts to repair the splenic injury through drainage or re-exploration would likely worsen bleeding and result in splenectomy.

CASE STUDY 2

1. **c.** In patients with a demonstrated early postoperative urine leak following partial nephrectomy, intervention is rarely required, as most leaks will resolve on their own with adequate drainage. While observation is almost

certainly the best course of action, renal imaging to evaluate for hydronephrosis and/or perirenal urinoma should be performed to determine the adequacy of drainage and the necessity for a stent or nephrostomy.

2. **b.** As the patient has a demonstrated urine leak with some hydronephrosis, further evaluation is warranted to ensure the kidney is well drained. In this case, placement of a stent may be warranted if ureteral obstruction is observed on retrograde pyelogram. Additionally, urine pooling around the proximal ureter could result in peri-ureteral fibrosis over time, with secondary obstruction and worsening of the leak. If a urinoma were to persist despite stent placement, then additional extrarenal drainage may be warranted. In this case, the difficulty of the case should also alert the surgeon to the possibility of an unrecognized ureteral injury, given the need for sharp release and traction on the ureter. Stent or nephrostomy would only be warranted if hydronephrosis or suspicion for ureteral injury is noted, or in the event of a large urinoma surrounding the lower pole or proximal ureter.
3. **b.** While nephrostomy drainage may ultimately be required if the persistent leak is not resolved by replacing the urethral catheter, at present, the primary goal should be to drain the extrarenal collection in order to allow the leak to scar in and to avoid periureteral fibrosis. In this case, the patient should have been imaged prior to discharge from the hospital in order to determine no residual urinoma was present upon diminishing drain outputs.

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35 Complications of Robotic Upper Urinary Tract Reconstruction

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CHAPTER OUTLINE

Preoperative Considerations
Operative Planning
Intraoperative Complications
Minimally Invasive Pyeloplasty
Minimally Invasive Ureteral Reconstruction
Minimally Invasive Ureterolysis
Minimally Invasive Buccal Mucosa Graft Ureteroplasty
Minimally Invasive Renal Autotransplantation
Postoperative Complications
Minimally Invasive Pyeloplasty
Minimally Invasive Ureterolysis
Minimally Invasive Ureteral Reimplantation
Minimally Invasive Ureteroureterostomy
Minimally Invasive Boari Flap
Minimally Invasive Buccal Mucosa Ureteroplasty
Minimally Invasive Ileal Ureter
Minimally Invasive Ureterocalicostomy
Minimally Invasive Transureteroureterostomy
Conclusions
Chapter 35 Questions and Answers

KEY POINTS

1. All upper tract reconstructive procedures have been performed safely and effectively using minimally invasive techniques, including laparoscopic and robotic surgery.
2. Thorough preoperative planning is critical for upper tract reconstruction, including preoperative imaging geared toward the type of surgery being performed and counseling about the different types of reconstruction that may be required depending on intraoperative findings.
3. Minimizing manipulation of tissue during upper tract reconstruction is critical to reduce risk of ureteral stricture and urinoma formation.
4. Maximal drainage of the urinary tract after upper tract reconstruction (i.e., ureteral stent placement, percutaneous drainage, and bladder drainage) reduces the risk of urine leakage and urinoma formation postoperatively.

The role of minimally invasive techniques in urologic surgery has burgeoned since the late 1990s. As intracorporeal suturing is a challenging aspect of laparoscopic reconstruction, there has been more widespread adoption of robotic techniques. Reconstruction of the upper urinary tract includes but is not limited to the following procedures: pyeloplasty, ureteroureterostomy, retrocaval ureter repair, ureteral reimplantation, psoas hitch or Boari flap, ileal ureter, ureterolysis, and renal autotransplantation. Buccal mucosa ureteroplasty is a new procedure that has been added to the armamentarium. This approach may be used if a ureteroureterostomy is not possible due to the length of the ureteral stricture, limited ureteral mobility due to radiation or fibrosis, or if a concomitant stricture exists in another location of the ureter. Robotic-assisted laparoscopic renal autotransplantation has been described recently, demonstrating the feasibility of using minimally invasive approaches for these cases.[1]

Complications may result from both technical and patient-related factors, although meticulous technique can help to minimize morbidity. Comfort with open surgical techniques is essential for any minimally invasive surgery to ensure competent intervention when conversion to an open procedure is required. This chapter reviews preoperative considerations and the management of complications.

Preoperative Considerations

OPERATIVE PLANNING

Reconstruction of the upper urinary tract relies on a thorough understanding of a patient's anatomy related to both disease and anatomic variation. Planning for pyeloplasty should include computed tomography (CT) or magnetic resonance imaging (MRI) with contrast to assess for crossing vessels and delineate hilar anatomy. Diuretic renal scans are useful to assess relative renal function and extent of obstruction. Additionally, if minimally invasive

ureterolysis is planned, biopsy of retroperitoneal tissue should be considered before ureteral manipulation to exclude malignancy.

Patients may have a mechanical bowel preparation before reconstructive urologic surgery to increase working space and improve exposure. A bowel preparation may also be useful for upper urinary tract reconstruction if harvesting bowel for ureteral interposition is planned.

The decision to use minimally invasive techniques depends primarily on the surgeon's preference and experience. Regarding the use of laparoscopy alone versus robotic assistance, few data suggest superiority of one technique over the other. Selection of transperitoneal versus retroperitoneal approaches for reconstruction depends primarily on the surgeon's preference. Both approaches are safe and effective for upper urinary tract surgery.[2–5] A comparative study evaluated retroperitoneal robotic pyeloplasty and transperitoneal robotic pyeloplasty.[5] Average operative time was similar, and there were no intraoperative complications. There were two recurrences in the retroperitoneal group and none in the transperitoneal group; notably the recurrences occurred in the first 10 cases. Retroperitoneal access may be safer in patients with extensive prior abdominal surgery and obesity, although disadvantages include limited working space and a potentially steeper learning curve.[6]

INTRAOPERATIVE COMPLICATIONS

General principles of perioperative care apply to patients having urologic reconstruction and include the use of bilateral sequential compression boots, prophylactic antibiotics, and generous padding for all pressure points.

Complications related to access and pneumoperitoneum are discussed in Chapter 30. This section describes complications specific to minimally invasive reconstructive procedures and recommendations regarding their management.

MINIMALLY INVASIVE PYELOPLASTY

Laparoscopic pyeloplasty was first described in 1993 and became the standard of care.[7,8] Robotic assistance was first reported by Sung and colleagues in 1999,[9] and numerous series have been published demonstrating the equivalence or superiority of this technique.[10–13]

In a series of 147 patients who underwent laparoscopic transperitoneal pyeloplasty, two cases of bowel injury were reported, including a serosal injury to the small bowel and an inadvertently clipped colonic diverticulum.[14] Both injuries were repaired during the same surgical procedure with no sequelae. No intraoperative complications were reported in a large series of patients who underwent extraperitoneal laparoscopic pyeloplasty.[4] In a multi-institutional series of robotic pyeloplasty among 140 patients, a single minor intraoperative splenic laceration was noted and successfully managed with pressure and topical hemostatic agents.[15] In another series of 131 patients, there was only one conversion to open surgery due to technical difficulties.[16] A multiinstitutional study of 168 patients undergoing robotic pyeloplasty reported no intraoperative complications.[17] Notably 21 (13%) of these cases were secondary repairs.

The reported rate of conversion from laparoscopic to open pyeloplasty is ≈1.6%.[2–4,18] Rassweiler and associates[19] reported a single conversion in their large series of retroperitoneal laparoscopic pyeloplasty based on significant anastomotic tension and the requirement for open dissection and fixation of the kidney during suturing. Mufarrij and associates[15] reported no open conversions in a series of 140 robotic pyeloplasties, whereas another study noted one open conversion out of 131 cases.[16]

The risk of significant bleeding from laparoscopic or robotic pyeloplasty is low. Inadvertent injury to major vessels may be minimized with good operative planning including CT with contrast to identify crossing vessels or anomalous vascular anatomy. However, in our experience, imaging may not be completely reliable; both false-positive and false-negative results of imaging for relevant vessels may occur.

Laparoscopic suturing is the most challenging aspect of laparoscopic pyeloplasty. Technical complications of suturing (e.g., stricture, urinary extravasation) may be minimized by meticulous technique, but patient-related factors (e.g., history of diabetes, secondary repair) may influence the incidence of these complications. Creating a tension-free anastomosis requires careful intraoperative planning and may decrease the risk of complications related to ureteral ischemia and suture line breakdown. Intraoperative techniques for safely creating more length include downward nephropexy and creation of a "handle" in the renal pelvis to decrease the manipulation of healthy tissue. Traction sutures can also be placed in the ureter or pelvis to decrease manipulation of tissue and decrease the risk of ischemia.

Ureteral stent placement across the anastomosis is essential to minimize the risk of urinary leakage. Complications of stent placement include submucosal tunneling and incomplete advancement into the bladder or kidney, depending on the direction of placement. If anterograde placement is performed, the bladder can be filled with 300 mL of methylene blue; refluxed dye confirms correct distal positioning of the stent. Flexible cystoscopy can also be performed to confirm correct placement of the ureteral stent.[20]

MINIMALLY INVASIVE URETERAL RECONSTRUCTION

Laparoscopic and robotic ureteral reconstruction has been performed in all portions of the ureter for diverse indications including trauma, stricture, neoplasm, and anatomic abnormalities.[21–25] Procedures have included ureteroureterostomy, ureteral reimplantation with or without psoas hitch, Boari flap, ileal ureter, ureterolysis, and retrocaval ureter repair. A novel procedure using buccal mucosa graft for ureteral repair has been developed.[26]

Laparoscopic ureteroureterostomy was first reported for treatment of infiltrative endometriosis and has been performed without significant intraoperative complications or need for conversion to an open procedure.[27] Robotic approach has also been used safely and successfully for ureteroureterostomy.[28,29] A unique consideration for ureteroureterostomy relates to the "watershed" blood supply of the midureter and the potentially increased risk of ischemia during manipulation and suturing. Techniques

for reducing the risk of ischemia include minimizing the manipulation of tissues (e.g., using traction sutures), minimizing medial dissection of the ureter and potential disruption of the vascular supply, and ensuring that the ureteral edges appear pink and healthy before anastomosis. A new technique developed by Lee and associates[30] was described to reduce the risk of injury to the ureter during surgery and to assist in localizing the ureteral stricture during repair. The authors used indocyanine green in an antegrade and retrograde fashion into the ureter and visualized it using near-infrared fluorescence during repair. A recent modification is the use of indocyanine green intravenously to evaluate tissue perfusion. Ureteral tissue appears dark if poorly perfused and bright green if well perfused. This technique has since been used by other groups to minimize complications related to poor blood supply.[31–33]

Ureteral stent placement is recommended in all patients having ureteral repair and can be placed preoperatively or intraoperatively in a retrograde fashion or transperitoneally during the surgery. If the ureteral length is insufficient for primary anastomosis, techniques such as psoas hitch or Boari flap can be performed to gain length distally. Buccal mucosa graft ureteroplasty, bowel interposition, or autotransplantation may be necessary if other techniques are unsuccessful. Understanding the patient's anatomy and extent of disease is essential to ensure appropriate operative planning and management of the patient's expectations preoperatively.

Despite limited data, evidence indicates that the intraoperative complication risk of ureteral reconstruction is low. No significant intraoperative complications were noted in series of laparoscopic and robotic ureteral reimplantation (for indications including reflux, distal ureter injury, and low-grade distal ureteral urothelial cell carcinoma),[21,25,34] Boari flap,[35,36] ureteroureterostomy,[37] ureterocalicostomy,[38,39] ileal ureter,[40] and retrocaval ureter repair.[23,41,42] One study of robotic ureteroureterostomy in 12 patients reported a liver and gallbladder laceration during robotic port placement due to adhesions which required a concomitant cholecystectomy.[43] Conversion to open was reported in one out of 16 patients who underwent robotic ureteral surgery. The patient had a prior history of pancreatectomy, and open conversion was needed to complete distal ureteral resection with reimplantation and psoas hitch for cancer.[44]

A study compared open, laparoscopic, and robotic ureteral reimplantation in 130 patients.[45] In the laparoscopic group, there was a 5% rate of intraoperative complications including inadvertent ureterotomies repaired primarily, enterotomy requiring small bowel resection, and injury to appendix requiring appendectomy. There was a 2% rate of conversions to open in the laparoscopic cohort, one for small bowel resection and another for technical difficulty. There were no complications or conversions in the robotic or open cohort. Robotic approach allows for better visualization, easier suturing, and improved hemostasis resulting in minimal complications. An additional two studies compared a total of 35 robotic to 65 open ureteral reimplants and found significantly less blood loss and shorter hospital stay for the robotic group.[46,47] These reports suggest that robotic ureteral reconstruction seems to be at least equivalent to the open approach, but may offer the additional benefits of minimal blood loss and shorter hospital stay.

MINIMALLY INVASIVE URETEROLYSIS

Laparoscopic ureterolysis was first reported by Kavoussi and associates in 1992.[48] Laparoscopic dissection within a fibrotic retroperitoneum can be challenging given diminished tactile feedback. However, low morbidity was reported in several series of laparoscopic ureterolysis.[49,50] Indocyanine green or intraoperative ultrasound can help to identify the ureter if fibrosis obscures retroperitoneal anatomy.[51]

Ureteral injury is one potential complication of laparoscopic ureterolysis. Ureteral injuries should be repaired with either a minimally invasive approach or with an open procedure, based on the extent and location of injury. Omental wrapping or intraperitonealization can be performed to protect the ureteral anastomosis. Rare complications include vascular injury, for example, an iliac vein injury,[35] pneumothorax, and subcutaneous emphysema.[52,53]

Reported conversion rates to open procedures have been 15% in series of laparoscopic ureterolysis.[35,49] Conversion has been required secondary to technical difficulty with periureteral fibrosis, vascular injury, and other emergency indications.

Robotic ureterolysis has been safely performed without intraoperative complication.[51] Improved visualization from robotic technology may facilitate identification of the ureter, and the precision of robotic Pott scissors and greater degrees of freedom may facilitate the dissection and potentially decrease the risk of injury.

MINIMALLY INVASIVE BUCCAL MUCOSA GRAFT URETEROPLASTY

Oral mucosal graft for ureteroplasty was first reported in an animal model in 1984.[54] Ureteral strictures have been treated successfully with buccal mucosa with an open approach.[26,55–57] In a study of five patients, buccal mucosa graft was used for strictures between 3.5 cm and 5 cm. There were no intraoperative complications, and at a mean follow-up of 24 months there was a 100% success rate. Robotic buccal mucosal ureteroplasty was done in four patients in one study, and there were no intraoperative complications. Some of the intraoperative maneuvers to ensure a successful repair were as follows: use of an omental flap or a perirenal flap to provide a vascular bed, simultaneous flexible ureteroscopy to localize the stricture, intravenous injection of indocyanine green to identify well-vascularized ureteral tissue, and flexible ureteroscopy during anastomosis to prevent placement of suture into the back wall of the ureter and to confirm a watertight anastomosis.

MINIMALLY INVASIVE RENAL AUTOTRANSPLANTATION

A technique of completely intracorporeal renal autotransplantation has been recently described in a patient with long ureteral stricture due to ureteral perforation during endoscopic stone treatment.[1] Warm ischemia time for nephrectomy was 2.3 minutes, while cold ischemia time was 95.5 minutes. Total console time for the surgeon was

334 minutes. The patient was discharged home on postoperative day 1 after a transplant Doppler ultrasound showed patent vascular anastomosis and after removal of Foley catheter and drain. The ureteral stent was removed at 6 weeks. A intravenous urogram 2 weeks after stent removal showed no extravasation or obstruction.[1]

Postoperative Complications

Most complications of laparoscopic or robotic surgery are postoperative.[2–4] In addition, intraoperative injuries may not be recognized until the postoperative period. Symptoms that cannot be explained by physical examination or routine studies should prompt further evaluation. CT can lead to diagnosis in most patients with unexplained pain, fever, leukocytosis, or decreasing hematocrit following urologic minimally invasive surgery.[58] See Chapter 30 for a thorough discussion of general postoperative complications of urologic minimally invasive surgery, including trocar site hernia or infection, ileus or bowel injury, bleeding, and medical complications. This section discusses postoperative complications specific to minimally invasive upper urinary tract reconstruction.

MINIMALLY INVASIVE PYELOPLASTY

See Table 35.1 for a summary of postoperative complications from major series of robotic pyeloplasty. These studies did not use standardized definitions of complications and thus may not be directly comparable. Minor and major complications were often grouped together in determining the total complication rate in these studies.

The reported postoperative complication rate for laparoscopic pyeloplasty is 2–22%.[19,59,60] A meta-analysis of laparoscopic pyeloplasty series revealed an 8% postoperative complication rate including hematoma, urinoma, pyelonephritis, bowel serosal injury, transient ileus, thrombophlebitis, and ureteropelvic junction (UPJ) anastomotic stricture.[61] Increasing experience with laparoscopic pyeloplasty within series revealed decreasing rates of postoperative complications.[59] Extraperitoneal laparoscopic pyeloplasty has published complication rates of ≈13%.[2–4]

Postoperative complication rates for robotic pyeloplasty have also been low, ranging from 3% to 11%.[10,15,17,20,62] The complications include urinary tract infection or pyelonephritis, ileus, stent migration or malposition, urine leak, bleeding requiring transfusion, recurrence of obstruction, and complications from operative positioning. Postoperative pyelonephritis may be treated successfully with antibiotics.[16] Stent migration or malposition requires repositioning under general anesthesia. It may be prevented by performing flexible cystoscopy to confirm a curl in the bladder at the time of surgery. Urine leak generally requires diversion of urine with Foley catheter, stent, or nephrostomy tube. If there is a urinoma, percutaneous drain placement into the urinoma in conjunction with diversion of urine may treat the complication. Bleeding may result in the formation of a clot in the renal pelvis requiring stent placement.[17] The renal pelvis should be irrigated before closure to minimize the likelihood of this complication. The failure or recurrence rate is low, but requires repeat pyeloplasty or endopyelotomy.[20] Positioning complications may include gluteal necrosis and rhabdomyolysis.[15] This can be prevented by decreasing operative time and not flexing the table, especially for obese patients, to allow more even distribution of

Table 35.1 Postoperative Complications of Robotic-assisted Laparoscopic Pyeloplasty

Reference	No. Procedures	Postoperative Complication Rate (No. Patients)	Postoperative Complications (No. Patients)
Hopf et al. (2016)[101]	129	13.9% (18)	Clavien I (3), II (5), III (10)
Sivaram et al. (2012)[17]	168	6.6% (11)	Ileus (4), transfusion (3), pyelonephritis (1), urine leak (3)
Mufarrij (2008)[28]	140	7.1% (10) (major) 2.9% (4) (minor)	*Major:* stent migration (7), clot obstruction, gluteal compartment syndrome requiring fasciotomy, pyelonephritis/obstruction *Minor:* febrile UTI, urine leak (2), splenic laceration (intraoperative)
Schwentner et al. (2007)[10]	92	3.3% (3)	Bleeding into renal pelvis/colic with urine extravasation requiring stent exchange and PCN, bleeding into collecting system 2 days postoperatively initially managed conservatively then requiring open pyeloplasty 3 mo later, insufficient closure of resected renal pelvis and excessive urine extravasation requiring transperitoneal exploration and primary closure of renal pelvis
Weise and Winfield (2006)[62]	31	6.5% (2)	Afebrile UTI, urine leak with ileus treated nonoperatively
Palese et al. (2005)[102]	35	11.4% (4)	UTI requiring oral antibiotics, pyelonephritis requiring IV antibiotics (2), gluteal compartment syndrome
Patel (2005)[103]	50	2% (1)	Renal colic after stent removal at 21 days requiring restenting (retrograde pyelogram showed widely patent anastomosis)
Bernie et al. (2005)[104]	7	28.60%	Febrile UTI requiring IV antibiotics, gross hematuria from bleeding at anastomotic site requiring readmission and conservative treatment
Gettman et al. (2002)[11]	9	11% (1)	Urinary leakage requiring open exploration and repair of incompletely closed renal pelvis

IV, intravenous; PCN, percutaneous nephrostomy; UTI, urinary tract infection

weight. Another rarely reported complication is bowel injury, especially in patients with a history of colitis.[16]

In another series of 92 patients undergoing robotic-assisted laparoscopic pyeloplasty, three patients (3%) had early complications requiring reintervention.[10] The first patient required stent exchange and percutaneous nephrostomy tube placement for a clot-related obstruction of the renal pelvis and colic with urine extravasation; the second patient bled into the collecting system 2 days postoperatively and, despite conservative treatment, required open secondary pyeloplasty; and the third patient, who had excessive urine extravasation after inadequate closure of the renal pelvis, required open repair of the renal pelvis. This last patient had prior treatment of UPJ obstruction but the exact treatment was not mentioned. Two other patients in this series had prior pyeloplasty, and nine had prior endopyelotomy or ureteroscopy, none of whom had significant complications. In a series of 31 patients with robotic-assisted laparoscopic pyeloplasty, one patient had nonfebrile urinary tract infection and one had a urine leak with ileus that was treated nonoperatively.[62]

Bleeding or hematoma formation can occur following minimally invasive pyeloplasty. Soulie and colleagues[2] reported that two of 61 patients developed hematoma in the lumbar fossa following laparoscopic pyeloplasty. Rassweiler and associates[19] reported five cases of postoperative hematoma in 143 patients undergoing laparoscopic pyeloplasty. Hematoma can generally be managed conservatively by following serial hematocrit levels and transfusing as necessary. Hemodynamic instability or a precipitous drop in hematocrit may necessitate urgent reoperation. One may need to drain a hematoma percutaneously at a later point based on persistent symptoms or infection.[2–4] CT scan is generally the best modality for diagnosing postoperative hematoma.[58] Delayed bleeding can occur as well; in one series, a patient required hospitalization for retroperitoneal bleeding 1 month after laparoscopic pyeloplasty.[14]

Urinoma is another important complication following minimally invasive pyeloplasty. Urine leakage occurs in ≈2.3% of patients undergoing laparoscopic pyeloplasty,[14,60] and this complication can occur despite meticulous suturing and ureteral stent placement. Urinoma may be indicated by flank or abdominal pain, fever, or elevated liver function tests on the right side.[58] Soulie and colleagues[2] reported that two of 61 patients developed postoperative urinoma. Rassweiler and colleagues[19] reported urinary extravasation in two of 143 patients after laparoscopic pyeloplasty. Secondary pyeloplasty and congenital abnormalities may be risk factors for urinary leakage.[11,12]

In the early postoperative period, leakage can be detected by persistently elevated drain output and can be confirmed by checking fluid creatinine levels. Drains may be required for a prolonged period if leakage persists. Within a urinoma, drains can be repositioned if necessary, including laparoscopically.[14,63] If one suspects urinoma after the acute postoperative period, CT with intravenous contrast is the diagnostic modality of choice. Delayed images may be needed to reveal active urine leak. Urinomas can generally be managed conservatively by leaving stents in place to optimize drainage or by replacing stents for ≥2 weeks and then assessing drainage of the upper urinary tract. Placement of a Foley catheter, or leaving the catheter in place, may also decrease pressure on the upper urinary tracts and maximize healing if leakage is noted. Percutaneous drainage of the urinoma may be required if conservative measures fail.[64] Percutaneous drains may be gradually extracted and serial imaging done to ensure resolution of the collection. Reactive pleural effusions can result from urinary leakage abutting the diaphragm; these effusions may require drainage if symptoms develop or if infection is a consideration. The risk of urinary leakage may be reduced by control of suture tension during collecting system closure.[65] Generally, urinary leakage has no significant sequelae, but periureteral scarring can occur. Repeat laparoscopy to suture an insufficiently closed site is rarely necessary but may be performed.[66]

Stent obstruction can occur after minimally invasive pyeloplasty. Rassweiler and colleagues[19] reported that one of 143 patients developed stent obstruction after laparoscopic pyeloplasty. A second stent can be placed, the stent can be changed, or percutaneous nephrostomy tube placement with or without anterograde stenting may be necessary. Stent migration can also occur requiring repositioning through ureteroscopy or removal, depending on timing relative to surgery.[67] If stent migration below the anastomosis is identified late, stenosis may require reoperation. Proper positioning of the double J stent should be carefully confirmed before leaving the operating room,[67] and erring on the side of longer versus shorter ureteral stents may be helpful. Acute obstruction after stent removal may require repeat stenting or nephrostomy tube placement. If a patient presents with ipsilateral flank pain before stent removal, imaging (e.g., kidneys, ureters, bladder) should be performed to ensure the stent is in the proper position.

Stricture at the UPJ following stent removal causes obstruction 2.5–3.6% of the time.[68] Stenting or nephrostomy tube placement may be required to relieve obstruction in these patients depending on symptoms, the presence of infection, and serum creatinine concentrations.[59,64] Conservative treatment of stricture can be attempted, such as with balloon dilation or endopyelotomy. However, secondary pyeloplasty may ultimately be required, and alternative techniques such as ureterocalicostomy may be necessary depending on the patient's anatomy (e.g., insufficient renal pelvis for anastomosis). Stents are typically removed 4–6 weeks after repair and the anastomosis evaluated at 6–8 weeks by renal scan or intravenous pyelogram. Depending on the timing of restricturing, this process may be considered a treatment failure or a complication. Success rates for both laparoscopic and robotic pyeloplasty are high, and early restricturing is uncommon.[10,69] Mufarrij and colleagues[15] reported that three of 140 patients required treatment of recurrent stricture after robotic pyeloplasty; two patients required endopyelotomy and one required repeat pyeloplasty. These investigators attributed these failures most likely to ischemia or technical factors.

MINIMALLY INVASIVE URETEROLYSIS

Reported postoperative complications of laparoscopic ureterolysis have been mild and have included prolonged ileus, epididymitis, urinary retention, and port site erythema.[35] In a series of five laparoscopic ureterolysis procedures, one patient had a small perioperative ureteral leak that was

managed with prolonged Foley catheter drainage and ureteral stent placement.[51] No postoperative complications occurred after five robotic ureterolysis procedures reported in the same article.[51] A study of 17 robotic ureterolysis cases (21 renal units) reported one case of enterocutaneous fistula due to an unrecognized cautery injury requiring bowel resection.[70]

Postoperative complications of ureterolysis are similar to those listed earlier for pyeloplasty and may include urinary extravasation and ureteral obstruction secondary to recurrent fibrosis or ischemic changes in the ureter. In one study, seven (18%) out of 40 patients undergoing ureterolysis underwent a second surgery for persistent obstruction including endoureterotomy, ureteroureterostomy, ileal ureter, and autotransplantation.[20] Another study showed a similar secondary intervention rate; three of 21 (14%) renal units undergoing robotic ureterolysis required a redo robotic ureterolysis with ureteral reimplantation, robotic ureteroureterostomy, and laser endoureterotomy. Intraperitonealization and omental wrapping can help to decrease the risk of recurrent obstruction, although these procedures may be technically challenging. Efforts should be made to diagnose and treat the underlying cause of fibrosis if possible. Ureteral stent placement may be helpful to minimize the risk of postoperative urinary leak and obstruction.

Unusual complications of ureteral manipulation can occur during ureterolysis. One of our patients developed a midureteral leak after robotic ureterolysis with omental wrapping. Stent placement was performed but the patient had recurrent flank pain and a renal scan demonstrated partial mechanical obstruction. Ureteroscopy revealed a mild midureteral stricture as well as a ureteral diverticulum with a Weck clip within the lumen of the diverticulum that was likely placed during omental wrapping of the ureter in the setting of ureteral perforation and leak. Balloon dilation and stenting were performed and subsequent ureteroscopy revealed sealing of the diverticulum; however, the patient required subsequent laser endoureterotomy and balloon dilation for recurrent stricture.

MINIMALLY INVASIVE URETERAL REIMPLANTATION

Laparoscopic and robotic ureteral reimplantation have been shown to be safe, with a low postoperative complication rate. No postoperative complications were reported in one small series of patients who underwent laparoscopic reimplantation for distal ureteral stricture refractory to endoscopic management.[34] No major postoperative complications were noted in a small series of patients who underwent distal ureterectomy and reimplantation for low-risk ureteral urothelial cell carcinoma.[21] However, minor complications are not unusual after ureteral reconstruction. A study of 16 patients reported a 75% rate of 90-day postoperative complications. Sixty-two percent of those complications were Clavien grade I–II, including urinary tract infection, pneumonia, ileus, prolonged anastomotic healing, femoral nerve lesion with temporary leg weakness and pain, prolonged abdominal pain, and a corneal erosion. Thirteen percent of the complications were Clavien grade IIIb–IVa, including urinary leak and peritonitis and a silent myocardial infarction.[44] Conversion to open approach is an uncommon intraoperative complication during robotic ureteral reimplantation or ureteroureterostomy and was reported in two out of 16 patients (13%) in one study.[71] This series also had a Clavien grade IIIb complication of unrecognized enterotomy requiring additional surgery. Despite the complications, there was a 100% clinical and radiographic success rate at a mean postoperative follow-up of 6.4 months. A more recent study of 31 patients who underwent ureteral reimplantation also reported a 100% radiographic and symptomatic success rate, with a 13% rate of Clavien grade I–III postoperative complications.[20] The robotic approach has also been used successfully in the challenging cases of post–radical cystectomy ureterointestinal stricture[72,73] and will be used more often as experience with intracorporeal urinary diversions increases.

Stricture can occur at the site of anastomosis following minimally invasive reimplantation. A study of 61 pediatric patients who underwent robotic extravesical reimplantation of 93 ureters showed a 10% complication rate including 5% rate of ureteral obstruction, 3% rate of urine leak, and 2% rate of readmission for nausea and vomiting.[74] The diagnosis can be made initially with renal ultrasound and then confirmed by excretory urography. Confirmation of drainage at the time of stent removal can minimize the risk of patients who present again with obstruction. Ureteral stent placement is generally indicated to drain the obstructed system, although percutaneous nephrostomy tube placement may be necessary. Stricture can be managed conservatively with dilation, but it may ultimately require anastomotic revision. Obstruction secondary to edema can occur postoperatively and is generally minimized by stenting for 4–6 weeks postoperatively; however, transient obstruction can also occur after stent removal and may require stent replacement for several weeks.[21]

Urinary leakage can occur following ureteral reimplantation and can be managed as discussed earlier with maximal drainage and consideration of percutaneous drain placement. A cystogram should be performed at the time of stent removal to confirm the absence of leak. Reflux into the ureter through the repair confirms patency of the anastomosis, provided a refluxing anastomosis was performed. If a nonrefluxing anastomosis was performed, diuretic renal scan, CT urogram, or an intravenous pyelogram can be performed to confirm the absence of obstruction at the ureterovesical anastomosis.

MINIMALLY INVASIVE URETEROURETEROSTOMY

The primary postoperative complications of laparoscopic or robotic ureteroureterostomy include anastomotic stricture and urinary leakage. However, published rates of postoperative complications for laparoscopic and robotic ureteroureterostomy have been low.[71,75,76] In a small series of ureteroureterostomy for iatrogenic injury of the pelvic ureter, no postoperative complications were noted ≈13 months after surgery.[77] Midureteral strictures have also been repaired laparoscopically with good results and without complications.[22] In a study of robotic ureteral reconstruction, eight patients underwent robotic ureteroureterostomy. There was a 25% Clavien grade III postoperative

complication rate; however, there was a 100% radiographic and symptomatic success rate.[20]

Obstructed retrocaval ureter has been repaired by laparoscopic and robotic resection of diseased retrocaval ureter and ureteroureterostomy without postoperative complications.[42,78,79] This procedure has been safely performed both transperitoneally and retroperitoneally.[80]

Laparoscopic and robotic ureteral surgery has been reported for upper urinary tract urothelial cell carcinoma and has been shown to be safe. Proximal ureteral segmentectomy and ureteropelvic anastomosis as well as distal ureterectomy with ureteral reimplantation have been performed for low-grade urothelial cell carcinoma without complications.[81,82] Oncologic outcomes at short-term follow-up have been encouraging in these patients. Patients should be carefully selected for any minimally invasive procedure for management of ureteral malignant disease, and principles of open oncologic surgery should be respected.

MINIMALLY INVASIVE BOARI FLAP

Laparoscopic Boari flap has been described for long distal ureteral strictures and has been shown to be safe and effective.[83,84] In a small series of laparoscopic Boari flap, one patient with a history of pelvic radiation developed urine in the peritoneum after Foley catheter removal.[83] The urinoma did not resolve with reinsertion of the catheter, and the patient required exploratory laparoscopy. Another small study of eight patients who underwent robotic ureteral reimplantation with Boari flap reported one case of anastomotic leakage postoperatively that was managed with prolonged catheterization.[85]

The risk of urine leakage can be minimized by leaving a Foley catheter in place for 7–10 days postoperatively and confirming the absence of a leak with cystography. In patients with a history of pelvic radiation, the Foley catheter should be left in place for ≥2 weeks to maximize healing. Ureteral stents should be left in place for 6 weeks to allow for complete healing of the ureter.

A small series of robotic ureteral reconstruction reported one case of robotic ureteral reimplantation with Boari flap that required conversion to open.[71] One of the larger robotic ureteral reconstruction studies evaluated 55 patients in a single institution who underwent robotic ureteroureterostomy, ureteroneocystotomy with psoas hitch and Boari flap. There were no intraoperative complications, median blood loss was 50 mL, and average hospital stay was 1.6 days. At a median follow-up of 181 days, there were three (5.3%) failures and two (3.6%) postoperative complications.[86] One patient needed exploratory laparotomy for bleeding several hours after the surgery, and another had oxygen desaturation due to multiple comorbidities requiring intensive care unit admission.

MINIMALLY INVASIVE BUCCAL MUCOSA URETEROPLASTY

Two cases of robotic buccal mucosa graft ureteroplasty were reported in a larger study of robotic ureteral reconstruction. Postoperative evaluation was with retrograde pyelogram 4–6 weeks after surgery at the time of stent removal and a Lasix renal scan 2–3 months after stent removal. In both patients, there was resolution of obstruction and symptoms at a mean follow-up of 8 months.[20] In a study of five open ureteral repairs with buccal mucosa, there were two early postoperative complications including fever, which responded to antibiotics and antipyretics, and ileus, which was managed conservatively.[55] Ultrasound done every month and intravenous urography done at 3, 9, and 12 months showed that all repairs remained unobstructed.[55] In another study of seven open buccal mucosa graft ureteroplasties, two patients were found to have impaired drainage at a median follow-up of 18 months.[56] To avoid any postoperative complications, in a study of four cases of robotic buccal mucosa graft ureteroplasty, a cystogram was done before removal of Foley catheter at 2 weeks, a retrograde or antegrade pyelogram prior to removal of stent at 6 weeks, an ultrasound after stent removal, and a renal scan at 3 months to assure patency.[33]

MINIMALLY INVASIVE ILEAL URETER

The first report of laparoscopic ileal ureter was reported by Gill and associates after laparoscopic ureterectomy for ureteral urothelial cell carcinoma in a patient with a solitary kidney.[40] No complications were associated with this procedure. Complications can arise from bowel manipulation and suturing including ileus, bowel obstruction, and bowel leak. Management of these complications is discussed in Chapter 11. Five other studies[87–91] of laparoscopic ileal ureter in 13 total patients have been published. Some of the postoperative complications included internal hernia that required exploratory laparotomy,[89] a urine leak requiring an additional percutaneous drain placement, pneumonia, and an enteric anastomotic leak requiring exploratory laparotomy, bowel resection, and reanastomosis.[90] Two case reports of robotic ileal ureter[92,93] have been published with no perioperative complications.

MINIMALLY INVASIVE URETEROCALICOSTOMY

Laparoscopic ureterocalicostomy has been performed without complications.[38] Robotic assistance may significantly facilitate the suturing component of this operation.[39,94,95]

MINIMALLY INVASIVE TRANSURETEROURETEROSTOMY

Laparoscopic transureteroureterostomy was reported in a series of three pediatric patients without significant postoperative complications.[96] Leaving a drain near the anastomosis is recommended to ensure the absence of leakage before the Foley catheter is removed. The literature on open transureteroureterostomy indicates an incidence of urinary leakage of ≈6%.[81]

Obstruction of the common ureter is noted infrequently in series of open transureteroureterostomy and has not been reported for laparoscopic transureteroureterostomy.[81,97–99] Intraoperatively, a stent can be placed either in the recipient ureter or across the anastomosis, although some investigators argue that stenting the recipient ureter is more useful for maintaining ureteral patency during the anastomosis and for preventing placing sutures through the back wall.[96]

Overall, series of open transureteroureterostomy demonstrate a low complication rate[100] and the rare occurrence of obstruction; in skilled hands, laparoscopic or robotic transureteroureterostomy is likely to have a similarly low complication rate.

Conclusions

In competent hands, minimally invasive urologic reconstruction is a safe and effective surrogate for open techniques. The intraoperative and postoperative complications are generally low for minimally invasive ureteral reconstruction surgeries. Inexperience with laparoscopic suturing was the main obstacle to the dissemination of these techniques into the community. As robotic techniques have become more popularized and demand from patients has grown for minimally invasive reconstruction, these techniques have become more prominent in urologic practice.

Unfortunately, reports of experience with minimally invasive surgery for ureteral reconstruction are mostly retrospective case series. Prospective, comparative trials are needed to assess superiority of these techniques to traditional approaches. Longer follow-up is also needed to evaluate whether radiologic and symptomatic success rates are sustained. Furthermore, many reports of complications for urologic reconstruction, and for much of urologic minimally invasive surgery, do not use standardized definitions of complications. Such standardization would help improve our understanding of the epidemiology of operative morbidity and would inform strategies to minimize the risk of these procedures. Modifying classification schemes to reflect urologic procedures specifically could increase the utility of reporting for our field.

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Chapter 35 Questions

1. Which statement is true regarding the Clavien–Dindo classification scheme?
   a. It is a classification system to grade complexity of robotic surgery
   b. Postoperative complications can be graded using this scheme from I to V, with V being death of a patient
   c. Ureteral injuries are rated using this classification system
   d. It is used to describe the degree of urine leak
   e. Postoperative complications can be graded using this scheme from I to V, with I being death of a patient

2. The most definitive way to confirm position of the stent intraoperatively during pyeloplasty is:
   a. When placing the stent robotically, one can visualize the stent markings through the repair
   b. Cystoscopy at the time of the stent placement
   c. Abdominal x-ray in the postoperative care unit
   d. Efflux of urine through the side holes of the stent
   e. Visualizing a curl in the renal pelvis

3. Which statement is false regarding indocyanine green?
   a. It is used when doing robot ureteral reconstruction to assess tissue perfusion
   b. It is a fluorescent dye injected intravenously
   c. Ureteral tissue appears bright green when poorly perfused and white when well perfused
   d. It can help identify ureteral fibrosis
   e. It can help identify the length of the ureteral stricture

4. Which of the following maneuvers prevents operative positional injuries during laparoscopic or robotic pyeloplasty?
   a. Placing the table on maximum flexion before surgery
   b. Not using additional padding for pressure points
   c. Minimizing the operative time
   d. Keeping the kidney rest to maximum elevation
   e. Not flexing or minimally flexing the table to allow for equal weight distribution

5. Which of the following is a unique complication of ileal ureter that does not occur with ureteroureterostomy or buccal mucosa graft ureteroplasty?
   a. Intestinal anastomotic leak
   b. Pyelonephritis or urinary tract infection
   c. Urinary leak
   d. Bleeding and need for transfusion
   e. Intraoperative bowel injury

6. Which of the following is an advantage of minimally invasive retroperitoneal renal surgery?
   a. Limited working space allows for surgical precision
   b. Retroperitoneal approach is easier to learn than transperitoneal approach
   c. It provides easier access to the ureterovesical junction than does the transperitoneal approach
   d. It is advantageous in those with extensive abdominal surgery
   e. It is proven to have a lower complication rate than does the transperitoneal approach

7. Which of the following is false regarding conversion of minimally invasive approach to open approach?
   a. Conversion to open may be done due to uncontrolled bleeding
   b. If there is extensive periureteral fibrosis, conversion to open may be necessary to facilitate dissection
   c. Conversion to open should never be done in a minimally invasive surgery
   d. Failure to progress with minimally invasive approach is an indication to convert to open
   e. Conversion to open is a reasonable option for an emergent situation

8. Which of the following surgical procedures has not been done with a minimally invasive approach?
   a. Ureteroureterostomy
   b. Ureterocalicostomy
   c. Renal autotransplantation
   d. Ileal ureteral substitution
   e. None of the above

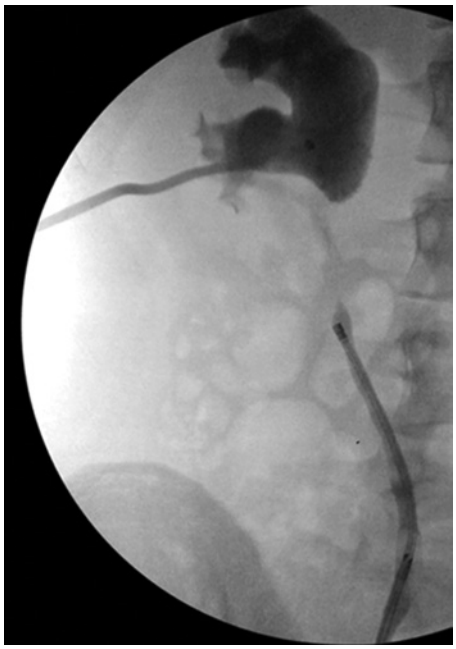
9. The complication rate of minimally invasive pyeloplasty is as follows:
   a. 0–25%
   b. 25–50%
   c. 50–60%
   d. 60–70%
   e. 100%

10. Following ureteral reimplantation surgery, the following exam is done prior to stent removal:
    a. Renal ultrasound to rule out urinoma and hydronephrosis
    b. CT scan to visualize the repair
    c. MR urogram to confirm that repair is healed
    d. Cystogram to confirm reflux (patency of repair) and rule out a leak
    e. Renal scan to rule out obstruction

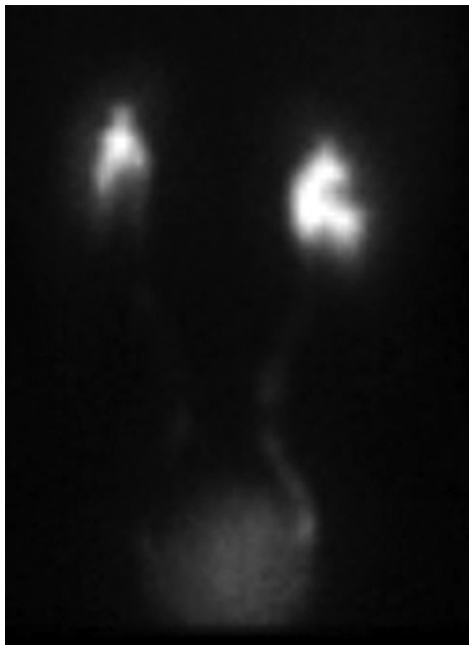
Case Studies

CASE 1

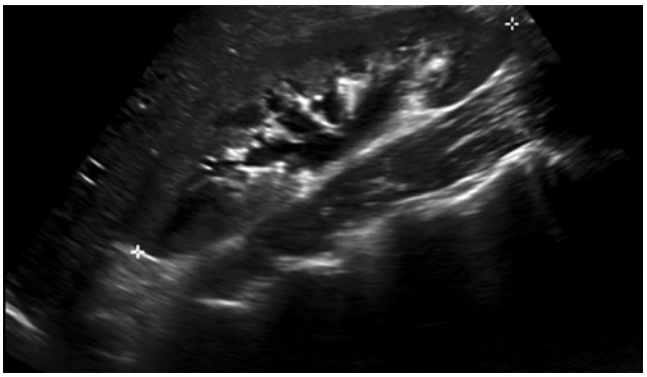
An 18-year-old male with history of ureteropelvic junction (UPJ) obstruction presented for evaluation. He had a history of right robotic pyeloplasty a year prior to presentation, which was complicated by a urine leak. After resolution of the urine leak, the patient developed a proximal ureteral stricture. Endopyelotomy was performed, which was unsuccessful. After a nephrostomy tube was placed, he underwent retrograde pyelogram and antegrade nephrostogram demonstrating a 4-cm proximal ureteral stricture (Case Fig. 35.1). A robotic buccal mucosa graft ureteroplasty was done. The ureteral stricture was opened ventrally in a longitudinal fashion. A



Case Figure 35.1 Antegrade nephrostogram and retrograde pyelogram reveal a 3-cm proximal ureteral stricture.



Case Figure 35.3 Tc-99m mercaptoacetyltriglycine renal scan showed prompt drainage of the collecting system without signs of obstruction.



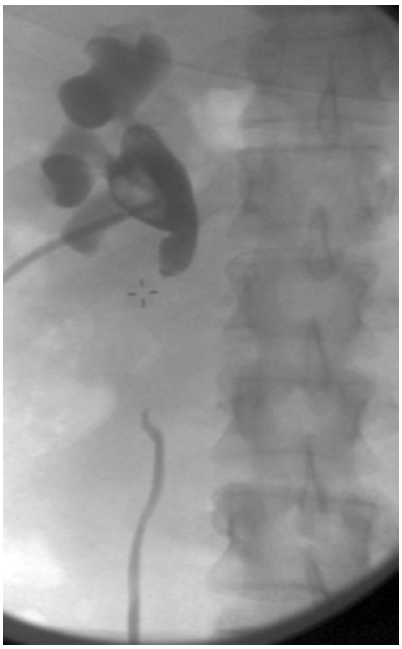
Case Figure 35.2 Renal ultrasound done 4 months after surgery reveals no hydronephrosis.

1.5-cm portion of the ureteral mucosa at the level of the stricture was excised leaving the dorsal adventia intact. The mucosal edges were reapproximated dorsally, and the ventral 3-cm defect was patched with a buccal mucosa graft. An omental flap was secured to the graft. Ureteroscopy was done during the suturing. A double J stent was left in place and confirmed to be in the bladder with cystoscopy. A percutaneous drain and Foley catheter were also left. The Foley catheter was removed on postoperative day 2. The percutaneous drain was removed the following day after drain creatinine returned consistent with serum. He was discharged with the nephrostomy tube capped. An antegrade nephrostogram was done 4 weeks later without evidence of extravasation, and the double J stent was removed. Four weeks subsequent to that, another antegrade nephrostogram showed a patent ureter and the nephrostomy tube was removed. At 4 months and 10 months after surgery, renal ultrasound (Case Fig. 35.2) confirmed no hydronpehrosis. A renal scan was done at 4 months and showed no signs of obstruction (Case Fig. 35.3).

1. Which of the following does NOT enable assessment of the length and location of a ureteral stricture?
   a. Renal and bladder ultrasound
   b. Antegrade and retrograde urography
   c. CT urogram
   d. Magnetic resonance (MR) urogram
   e. Intravenous pyelogram

2. Which intraoperative maneuver does NOT help in minimizing postoperative complications?
   a. Ureteroscopy to assure that the ureteral lumen is not closed during suturing and assess if the anastomosis is watertight
   b. Flexible cystoscopy to confirm correct placement of the double J stent
   c. Omental wrapping of the buccal mucosa graft to provide a vascular bed
   d. Not placing a percutaneous drain for patient comfort
   e. Using indocyanine green dye to assess ureteral perfusion

3. Which statement regarding postoperative maneuver to minimize complications after ureteral reconstruction is TRUE?
   a. Checking drain creatinine prior to drain removal is not useful
   b. A urographic study of the repair prior to double J stent removal helps rule out extravasation
   c. Renal ultrasound after stent removal provides no additional information



Case Figure 35.4 Antegrade and retrograde nephrostogram show a proximal ureteral stricture about 3 cm long.



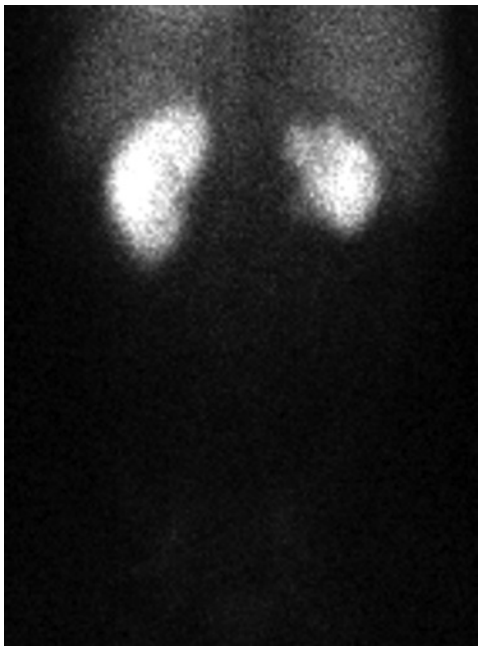
Case Figure 35.5 CT urogram showing a cortical defect in the upper pole of the kidney with contrast extravasating from the collecting system into the perirenal space.

d. The Foley catheter should be removed after stent removal
e. The nephrostomy tube should be removed first

CASE 2

A 29-year-old female presented after a motor vehicle accident and underwent exploratory laparotomy. Five days later she was diagnosed with a complete transection of the right ureter. A nephrostomy tube was placed. She developed a 3-cm ureteral stricture evident on antegrade and retrograde urographic studies (Case Fig. 35.4). She underwent a downward nephropexy and robotic ureterocalicostomy. This was complicated by fevers, and she was found to have an upper pole urine leak (Case Fig. 35.5) seen on CT urogram. A percutaneous drain was placed into the infected urinoma. She remained febrile, and another fluid collection above the kidney was found on repeat CT scan and drained. Imaging also demonstrated that the stent was malpositioned at the anastomosis. An antegrade nephroscopy was performed to reposition the stent. A month after this procedure, a nephrostogram was done demonstrating no leak, and the double J stent was removed. The nephrostomy tube was left capped. A month later a renal ultrasound was done and was normal, and the nephrostomy tube was removed. A renal scan (Case Fig. 35.6) was done 5 months after the original surgery and demonstrated no obstruction.

1. What is NOT an option for proximal ureteral stricture repair?
   a. Ureteral reimplantation with Boari flap
   b. Ureterocalicostomy
   c. Ureteroureterostomy
   d. Buccal mucosa graft ureteroplasty
   e. Ileal ureter



Case Figure 35.6 MAG-3 renal scan showing loss of function in lower pole of kidney at the site of ureterocalicostomy.

2. Which of the following is NOT an appropriate management for urinary leak?
   a. Placement of percutaneous drain into a urinoma
   b. Stent placement to maximize drainage of urine away from the leak
   c. Replace Foley catheter if it has been removed
   d. Immediate open exploration, washout, and repair
   e. Nephrostomy tube placement to maximize drainage of urine away from the leak

3. Which maneuver does NOT help preserve blood supply to the ureter during reconstruction?
   a. Placing holding stitches on the ureter for handling
   b. Ensuring that ureteral edges are pink and healthy prior to anastomosis
   c. Preserving periureteral adventitia to protect blood supply
   d. Widely spatulating the ureter prior to anastomosis
   e. Not using energy sources to cut or spatulate the ureter

Answers

1. **b.** It is a scheme used to grade postoperative complications, not the complexity of robotic surgery (a), ureteral injuries (c), or degree of urine leak (d). Grade V complication is a mortality, not Grade I (e).
2. **b.** Cystoscopy at the time of stent placement is the best way to confirm correct stent position intraoperatively. Visualizing the stent through the repair does not prove that the stent is positioned correctly within the bladder and may result in the stent being in the distal ureter instead of the bladder. Efflux of urine is not an accurate way to assure that the stent is positioned correctly. X-ray in the postoperative care unit can be helpful, but will not be helpful if the stent needs to be adjusted. Visualizing a curl in the renal pelvis will not assess if the stent is properly positioned in the distal ureter or bladder.
3. **c.** Ureteral tissue appears bright green when well perfused, as this indicates that the indocyanine green has made it to the ureter. All the other statements are true.
4. **e.** The table should be minimally flexed or not flexed as positional injuries usually result at points of maximum pressure. Placing the table on maximum flexion distributes weight unevenly and creates pressure points, which increases the chance of injury (a). Padding should be used for pressure points (b). Operative time should be kept as short as possible (c). Kidney rest should be avoided as it increases flexion and the chance for positioning injuries (d).
5. **a.** Ileal ureter has some unique complications including internal hernia and leak from the intestinal anastomosis. The other complications (b, c, d, and e) may occur in any of the ureteral repairs.
6. **d.** The minimally invasive retroperitoneal approach is useful in those with extensive prior abdominal approach and in obese patients. Disadvantages include limited working space and steep learning curve.
7. **c.** a, b, d, and e are true statements. Conversion to open is a reasonable option during uncontrolled bleeding, extensive fibrosis, or failure to progress or any emergent situation.
8. **e.** All the other ones have been described using a minimally invasive approach.
9. **a.** The complication rate of pyeloplasty is 2–22%.
10. **d.** Other imaging techniques do not provide adequate information to confirm potency of repair as well as rule out a urine leak.

CASE 1

1. **a.** Although renal and bladder ultrasound will confirm hydronephrosis, it is a poor study for evaluation of the ureter. Urography with fluoroscopic guidance, CT, or MRI will enable assessment of the length and location of the stricture. Delayed phase images are necessary when using CT or MRI. Intravenous pyelogram can help assess the length and location of the ureteral stricture; however, this test is not commonly used due to advancement in imaging technology.
2. **d.** Percutaneous drain should be placed to allow for maximal drainage in case of a urinary leak. This patient developed a urinoma after the pyeloplasty, which resulted in the ureteral stricture. Checking a drain creatinine prior to removal can help rule out a urine leak.
3. **b.** A retrograde or antegrade urography should be done to rule out extravasation prior to removal of the double J stent. Checking drain creatinine can help rule out urine leak, and if one is present, the drain should be kept until it heals. Renal ultrasound after stent removal is useful to rule out recurrent ureteral obstruction. The Foley catheter is removed first prior to drain or stent removal. The nephrostomy tube is removed last after a urographic study reveals no extravasation at the site of repair.

CASE 2

1. **a.** Ureteral reimplantation with Boari flap is used for distal and midureteral strictures. Stretching the Boari flap up to the proximal ureter could compromise the bladder function. Ureterocalicostomy, ureteroureterostomy, and buccal mucosa graft ureteroplasty are better options for proximal strictures. If the ureteral stricture is long and not amenable to repair, ileal ureter may be used.
2. **d.** Maximizing urinary drainage helps heal the urinary leakage site. Therefore a Foley catheter, a stent, or a nephrostomy tube should be placed along with a drain in the urinoma. Urinary leakage usually resolves with these conservative measures and open repair is unnecessary.
3. **d.** Widely spatulating the ureter ensures a patent anastomosis and prevents stricture formation. The other choices listed assist in maintaining ureteral blood supply.

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36 Complications of Robotic Cystectomy

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CHAPTER OUTLINE

Introduction
Review of Perioperative and Postoperative Complications
Comparisons Between Robotic and Open Radical Cystectomy
Factors Associated With Complications During Robotic Cystectomy
Perioperative Preparation
Patient Selection
Perioperative Pathways
Operative Equipment and Setup
Intraoperative Complications and Management
Ureteral Dissection
Posterior Dissection and Pedicles
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Issues Unique to Female Cystectomy
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Postoperative Complications and Management
Venous Thromboembolism
Wound Infection/Fascial Dehiscence
Lymphocele
Ileus
Anastomotic Leak and Enterocutaneous Fistula
Conclusions
Chapter 36 Questions and Answers

KEY POINTS

1. Complications following robotic cystectomy are common, estimated at 44% and 59% at 30 and 90 days, similar to open cystectomy series.
2. Optimizing perioperative care through enhanced recovery after surgery (ERAS) strategies include a number of preoperative, intraoperative, and postoperative maneuvers that can effectively reduce postoperative complications following robotic cystectomy.
3. Operative equipment and set-up for robotic cystectomy using surgical checklists can identify errors with robotic cystectomy and avoid preventable intraoperative complications.
4. Complications during ureteral dissection can be avoided through careful manipulation of the ureter, avoiding tension and crush injury and judicious use of monopolar and bipolar cautery.
5. Posterior dissection can be aided by use of a 30-degree up lens, judicious use of thermal energy, and releasing the anterior bladder attachments as late as possible.
6. By following the psoas muscle deep between the external and internal branches, also known as the Space of Marseille, the external iliac vein can be carefully observed and obturator dissection of the obturator nodes better facilitated.
7. To prevent injury, the obturator nerve must be identified visually prior to clips and ligation during robotic lymph node dissection.
8. Vascular injury during robotic cystectomy can be managed through direct pressure using mini lap sponges, avoiding direct pressure by robotic instruments which may cause further injury, allowing robotic suture possible.
9. Venous thromboembolism risk is similar for robotic and open cystectomy, and should be addressed similarly using the AUA Best Practice Statement for Prevention of DVT by providing extended 4 week prophylaxis when possible.
10. Postoperative complications following robotic cystectomy such as thromboembolism, lymphocele, ileus and anastomotic leak are similar to that of open cystectomy, and may be managed similarly.

Introduction

Bladder cancer is the fourth most common cancer among men and the 12th among women in the United States, with 74,000 new diagnoses each year.[1] While 75% of new diagnoses involve nonmuscle invasive bladder cancer, approximately 25% are diagnosed as muscle invasive, an aggressive malignancy. If left untreated, muscle invasive bladder cancer (MIBC) survival approaches 15% at 2 years.[2] Due to its high mortality rate, MIBC and high-risk nonmuscle invasive bladder cancer warrant aggressive treatment. Treatment options include radical cystectomy or trimodality therapy (with aggressive transurethral resection of bladder tumor, chemotherapy, and radiation). Traditionally, radical cystectomy has become the standard treatment for aggressive bladder cancer, but it can be fraught with a high complication rate and difficult recovery.

Complication rates for open radical cystectomy (ORC) vary from 28% to 64%,[3,4] with higher reported rates among studies using strict standardized reporting.[4] The most common complications include gastrointestinal complications, followed by infectious and wound-related complications. In an attempt to minimize the morbidity of ORC, laparoscopic cystectomy was introduced. Shortly thereafter, the development of robotic surgery refined the more challenging technique of laparoscopic cystectomy, and ultimately opened the door to robotic cystectomy as a feasible alternative to the traditional open approach. Since the first reported robot-assisted radical cystectomy (RARC) series in 2003,[5] robotic cystectomy use has increased along with the addition of robotic intracorporeal urinary diversions. Along with this increase has been accompanying literature comparing complications between robotic and open cystectomy, with widely ranging complications rates, even when utilizing strict reporting criteria.[4,6]

At the University of North Carolina and University of Alabama, dedicated efforts have focused on reducing complications through streamlined perioperative pathways, ensuring appropriate equipment and materials, and perfecting intraoperative techniques. Postoperative enhanced recovery pathways have reduced complications, and these efforts have expanded the ability to treat older patients in need of treatment for aggressive MIBC. By emphasizing these "lessons learned," this chapter focuses on a review of intraoperative and postoperative complications following robotic cystectomy and methods to reduce these rates. More specifically, the review will provide comparisons between complications associated with the traditional open approach and newer robotic approach, predictors of complications, and the importance of the learning curve when transitioning to robotic cystectomy. The chapter will conclude with strategies for avoidance of intraoperative complications, management of common intraoperative and postoperative complications, and advice for both beginning and seasoned robotic cystectomy surgeons.

Review of Perioperative and Postoperative Complications

Data regarding perioperative and postoperative complications following RARC continue to mature. Although a number of these studies include single-center analyses, several additional multi-institutional reports have been reported. Complication rates following RARC vary widely and may reflect differences in operative technique, experience, and postoperative care. Furthermore, some complications may occur at local, nontertiary hospitals and may not be systematically collected or reported. In the past, many studies did not adhere to standardized reporting guidelines, such as the Memorial Sloan Kettering Cancer Center (MSKCC) grading or the modified Clavien-Dindo classification systems.[4,7] However, contemporary studies now routinely report complications using these standardized criteria.

A recent multi-institutional study from the International Robotic Cystectomy Consortium described the complications after RARC using the MSKCC grading system.[8] Of 939 patients who underwent RARC with available complication data and at least 90 days' follow-up, 41% and 48% experienced a complication within 30 and 90 days of surgery, respectively. Approximately 19% of patients experienced a major complication, with gastrointestinal, infections, and genitourinary complications most commonly reported (27%, 23%, and 17%, respectively). On multivariable analysis, the authors found that increasing age, neoadjuvant chemotherapy, and receipt of blood transfusion were independent predictors of major complications.

To summarize the vast array of literature focusing on RARC complications, a recent systematic review identified over 105 articles describing both perioperative and postoperative complications among a variety of single and multi-institutional RARC studies.[6] The overall intraoperative complication rate for RARC was 3%, but 30- and 90-day complication rates were 44% (ranging from 26% to 78%) and 59% (ranging from 15% to 79%), respectively. Among those patients undergoing RARC and extracorporeal conduit diversion, overall 90-day complication rates were 59% (with major complications 15%). For complications following RARC with intracorporeal conduit diversion, 30- and 90-day complication rates were similar at 67% and 59%. Extracorporeal and intracorporeal neobladder complication rates differed somewhat, which may be related to patient selection, surgeon experience, and other factors. Extracorporeal continent diversion complication rates were as high as 77%, whereas overall complication rates for intracorporeal continent diversion were slightly lower at 45.7% for 30 days, and 30% between 30 and 90 days (with no studies exploring overall 90-day complication rates). However, the major complication rate was higher (28%) than that of extracorporeal diversions. Readmission rate overall was 19% for RARC with extracorporeal conduit[6] but as high as 75% in a small single institution study for RARC with intracorporeal neobladder.[9]

COMPARISONS BETWEEN ROBOTIC AND OPEN RADICAL CYSTECTOMY

Given that RARC is a relatively new technique, comparisons of its perioperative outcomes with the ORC gold standard have spurred great interest. Several single institution studies have compared consecutive ORC and RARC series, while attempting to control for selection bias and other factors. Investigators from the University of Michigan compared RARC to ORC complications using a 1:2 matched analysis on age, sex, diversion, and clinical stage.[10] The rate of

30-day minor or major Clavien complications and 30-day readmissions did not differ between operative techniques. These results have been confirmed in two single institution randomized controlled trials.

The first randomized trial comparing ORC and RARC was performed at the University of North Carolina and compared 20 patients undergoing ORC to 21 in the RARC cohort.[11] Although designed as a noninferiority study comparing lymph node yield, several secondary end points were evaluated, including complication rate. No difference in overall complication rates between ORC and RARC were noted (50% vs 33%, respectively; $p = 0.28$). However, RARC had a significantly lower estimated blood loss when compared to ORC (258 mL vs 575 mL; $p < 0.0001$). In a multivariate analysis controlling for age, body mass index (BMI), and pathologic stage there was a trend toward a lower complication rate in the robotic group, but it did not reach statistical significance ($p = 0.0503$).

A recently published randomized controlled trial from Memorial Sloan Kettering compared 90-day grade 2–5 complications between open and robotic cystectomy. Of 118 randomized patients, 60 were randomized to RARC and 58 to ORC, and 90 day complications occurred in 62% and 66% of RARC and ORC patients, respectively.[12] Estimated blood loss was lower in the RARC group by a mean of 159 mL ($p = 0.03$), but operative time favored the ORC group by a mean time of 127 minutes ($p < 0.0001$). The trial was closed early due to futility in its primary outcome (complication rate). Furthermore, no differences were noted for high-grade complications between treatment groups. The types of complications were similar in each arm, with infectious complications most common. The only difference found between techniques was with regard to wound complications, which were more commonly observed in ORC (14%) compared to RARC (3.3%). A multi-institutional randomized trial has completed accrual and will report complications of ORC and RARC by 2017, lending more evidence to any possible benefit of a particular approach.[13]

Among large-scale studies using administrative claims data, a recently published population-based study used data from the Premier database (an all-payer hospital discharge database) to compare complications between 34,000 ORC and 2100 RARC patients.[14] RARC volume increased from 0.6% in 2004 to 12.8% in 2010, with major complication rates (defined as Clavien grade 3 or higher) similar between groups (17% vs 19.8% ORC vs RARC; $p = 0.42$). However, RARC had a 46% decreased odds of minor complications compared to ORC ($p = 0.03$). Readmission rates were similar at 20% versus 18% ($p = 0.35$) when adjusting for pertinent confounders. Based on this and other studies, the overwhelming consensus is that high-grade complications do not differ based on ORC or RARC technique, with minor complications likely lower among RARC due to its lower risk of wound complications.

FACTORS ASSOCIATED WITH COMPLICATIONS DURING ROBOTIC CYSTECTOMY

In a recent systematic review and cumulative analysis, the impact of patient characteristics, aspects of surgery, and diversion type on RARC complications was evaluated.[6] In this analysis, two studies assessed the impact of BMI on RARC complications, with both failing to identify any differences based on this patient characteristic.[15,16] However, a larger multi-institutional study found that higher BMI was predictive of high-grade complications, even when controlling for other pertinent characteristics.[8] Another study evaluating predictors of readmission found that higher BMI predicted 30- and 90-day readmission rates on multivariable analysis.[17] Additional patient characteristics that appeared to predict complications following RARC included older age,[8,18] use of neoadjuvant chemotherapy,[8] and elevated preoperative creatinine.[18] Intraoperative variables predictive of complications included need for blood transfusion,[8] conduit diversion,[8] higher estimated blood loss,[18] and significant intravenous fluids greater than 5 liters.[18]

Given that age is a consistent independent predictor of significant complications following RARC in numerous studies, postoperative complications among octogenarians have also been specifically evaluated. At the University of North Carolina, 119 patients were divided into older and younger age cohorts (61 patients <70 years and 38 patients ≥70 years).[19] No significant differences were found with respect to postoperative outcomes or complication rates between older and younger patients. Another single institution study from Wake Forest University aimed to compare ORC and RARC outcomes among older patients.[20] Among 40 patients, evenly split into ORC and RARC cohorts with comparable preoperative characteristics, major complication rates were lower in the RARC group (10% vs 35%; $p = 0.02$), suggesting that RARC can be safely performed among older, albeit carefully selected patients.

Urinary diversion can also impact RARC complication rates, and to evaluate this relationship, a single institution study from the City of Hope Cancer Center analyzed 209 RARC patients, of whom 68% underwent continent diversion.[21] Within 90 days, 77.5% experienced a complication and 32% a major complication. Multivariable analysis revealed that patients undergoing ileal conduit diversion were less likely to experience complications when compared to Indiana pouch and orthotopic neobladder despite the increased comorbidities noted among conduit diversion patients. Continent diversion patients also were more likely to experience urinary tract infections, similar to open cystectomy series.

Beyond patient characteristics and surgical technique, an important predictive factor for complications following RARC is surgeon experience. The learning curve has been evaluated as a predictor of complications following RARC in a number of single and multi-institutional studies.[6] Conclusions vary based on the reporting institution, with some arguing that complication rates decrease with increasing experience[22–24] and others showing no difference.[25–27] In one single institution study evaluating 60 consecutive cases, 90-day complications decreased from 70% in the first 20 cases to 30% in the last 20 cases.[22] In contrast to these findings, a larger series of 164 patients at Roswell Park Cancer Institute demonstrated stable long-term complication rates, with no differences.[26] Complications following intracorporeal diversion also show mixed results regarding the impact of the learning curve, with some studies demonstrating 30- and 90-day improvements with experience,[23,24] while others showed little change in the first

100 cases reported.[27] Conflicting results are likely related to previous robotic experience, surgeon skill, institutional support, patient selection, and numerous other factors. However, all studies confirm that the learning curve can be overcome with experience. Indeed, centers with higher volume appear to have lower complication rates. In a large study from the IRCC of over 800 patients undergoing extracorporeal or intracorporeal urinary diversion, high-volume centers (defined as those institutions with >100 cases) had lower overall complications following RARC ($p = 0.002$).[28]

Perioperative Preparation

PATIENT SELECTION

Older patients are at risk for complications from cancer treatment, but chronologic age and physiologic age are not equivalent. An expert in cancer treatment in the elderly, Dr. Arti Hurria from the Cancer and Aging Research Group (CARG), defined a tool that predicts treatment toxicity, specifically chemotherapy, in older adults with cancer.[29] This tool included common predictive characteristics such as age, tumor type, treatment complexity, and laboratory values. For example, patients ≥72 years were at increased risk for toxicity, suggesting that the seventh decade of life represents a threshold at which treatment risk increases substantially. Another important risk predictor included anemia, which was independently associated with hospitalization, mortality, and diminished functional status among geriatric cancer patients. Patients with baseline anemia prior to their first cycle of chemotherapy were more likely to have impairments and disability in activities of daily living (ADL) in both self-reported as well as provider-observed functional assessments.[30]

Patients who undergo robotic cystectomy share similar baseline characteristics with the patient population studied by the CARG, but whether this translates to similar findings in the robotic cystectomy population is unknown. The IRCC noted that increasing age, neoadjuvant chemotherapy, and receipt of blood transfusions were associated with increased complications.[8] Although blood transfusion rate is closely linked to intraoperative blood loss (EBL), the IRCC demonstrated that only blood transfusion (not EBL) was associated with postoperative complications. Therefore preoperative anemia, potentially as a marker of global functional status, may be an underlying cause of complications among RARC patients. As part of our perioperative pathway, we carefully assess preoperative anemia in the preoperative setting, and although this does not preclude patients from RARC, these patients are more closely monitored perioperatively.

Beyond laboratory values, additional preoperative characteristics include global geriatric assessment elements such as physical functioning, psychosocial well-being, and social support.[29] A geriatric assessment tool is available online through the Center for Cancer and Aging (mycarg.org) and can be used as an adjunct for preoperative evaluation. At our institutions, we routinely use this tool and have recognized its value in both patient selection as well as risk counseling.

Additional perioperative risk calculators also exist, such as the American College of Surgeons (ACS) surgical risk calculator. The ACS surgical risk calculator was developed from data gathered by over 400 hospitals and 1.4 million surgical procedures identified in the National Surgical Quality Improvement Program database.[31] The calculator allows the user to input specific preoperative characteristics such as age, BMI, and gender to identify a patient's risk for 30-day morbidity and mortality after surgery (riskcalculator.facs.org). Benefits of this risk calculator include ease of use, quick implementation, and graphic output that can be easily shared and understood by the patient, facilitating the real-time informed consent process. With many tools available, providers can utilize these for patient selection and counseling. However, in the absence of rigorous research comparisons, the predictive ability of each calculator as it compares to the others is unknown.

PERIOPERATIVE PATHWAYS

While patient selection is the first step in the perioperative pathway, optimizing perioperative care is vital to reduce complication risk following RARC. Through ERAS (enhanced recovery after surgery) initiatives, high-risk patients are provided with better opportunities for decreased complications. Our practice involves a clinic visit prior to initiation of neoadjuvant chemotherapy in which we assess overall performance status, perform a comprehensive geriatric assessment, and highlight opportunities to improve health prior to cystectomy. Full details of our entire ERAS protocol are detailed in Table 36.1. Another easy-to-follow protocol for perioperative care after radical cystectomy has been published by the ERAS society.[32] Our institutions use these guidelines to establish standard order sets for our cystectomy patients, as they have demonstrated benefit among patients undergoing robotic cystectomy. A comparison of over 200 patients who underwent the standard protocol versus the enhanced recovery protocol was performed at the University of Southern California, demonstrating that patients on the enhanced recovery protocol used less opioids and had shorter length of stay.[33] Several institutions have shown similar findings and incorporate these pathways as a method to optimize postcystectomy care.[34]

OPERATIVE EQUIPMENT AND SETUP

Beyond patient-related perioperative optimization, operative equipment and setup can contribute to maximizing success and minimizing risk during RARC. Useful instruments and equipment are listed in Table 36.2 and described in detail throughout this chapter. Surgical checklists can also provide an additional layer of protection. The development of surgical safety parameters specific to robotic urologic surgery was recently described in a systematic review with rigorous methodology. This review provides an excellent safety checklist that can be used to identify errors within any robotic procedure, including RARC.[35] Several safety items include securing of the patient, equipment and instrument checks, and docking of the robot (Table 36.3).

An additional recommendation that can facilitate success in the operating room is a second time-out to define any new techniques or adaptation in technique. Verbalizing changes in technique can facilitate consensus within the

Table 36.1 Enhanced Recovery After Surgery Strategies

Timing	Enhanced Recovery After Surgery (ERAS) Strategy
Preoperative	Preoperative counseling and education Nutrition consultation Optimization of medical comorbidities Cessation of smoking, alcohol abuse, encouragement of physical activity No bowel preparation Alvimopan initiated
Intraoperative	Compression stockings Low-molecular-weight heparin before anesthesia induction Antibiotic prophylaxis (with redosing if prolonged case) Perioperative fluid management – avoiding overhydration and maintaining hemodynamic control Maintenance of normal body temperature No nasogastric tube (orogastric tube during case, removed at end of case) Ureteral stent placement Intraperitoneal drain placement
Postoperative	Alvimopan continued until return of bowel function Early mobilization Nonnarcotic analgesics Chewing gum as needed Early oral dietary advancement (sips on POD1, unlimited clear liquids on POD2, and regular diet on POD3) Continued enoxaparin prophylaxis for 4 weeks post-surgery Nutrition consultation Early drain removal if warranted Stent removal within 10–14 days with antibiotic prophylaxis

operating room team by placing focus on the patient and can be helpful whether early or late in a surgeon's learning curve. This second time-out can also allow anesthesia an opportunity to provide an update on the patient, nursing to check for shifts in positioning, and the surgeon to assess whether progress is sufficient to warrant proceeding with the robotic approach.

Success with the robotic approach can also be greatly affected by trocar placement.[36,37] To ensure success, the camera port should be placed at least two fingerbreadths above the umbilicus to facilitate cephalad extent of the lymph node dissection as well as intracorporeal bowel work. If considering intracorporeal diversion, the fourth arm should be placed on the patient's left side to facilitate use of the robotic stapler. However, if a laparoscopic stapler will be used (with an assistant), the robotic fourth arm should be placed on the patient's right side to minimize tension on the bowel during staple fire. In an effort to decrease the learning curve between extracorporeal and intracorporeal urinary diversion, an additional 12-mm trocar in the lower midline can facilitate stapling of the bowel segments.[36] Furthermore, the intracorporeal diversion can be better facilitated by undocking and removing 15–20 degrees of steep Trendelenburg for the extirpative portion of the bowel work.

Intraoperative Complications and Management

URETERAL DISSECTION

Initial ureteral identification typically starts with the left side. The surgeon should mobilize the white line of Toldt

Table 36.2 Useful Instruments for Robotic Cystectomy and Lymph Node Dissection

Type	Product Name	Comments
General		
	EA sizer set	Rectal injury
	Mineral oil	Prelubed wire, run inside stent to facilitate easy removal during case
	AirSeal insufflation system	Stable insufflation, allows continuous suction if needed, avoid loss of insufflation on female cases w/open vaginotomy; also easier to remove LN packets as no valve on port
	Mini lap sponges	Utilized in case of vascular injury for pressure if needed
Robotic		
	Robotic clip applier	Assistant having difficulty, allows for better angle; charged per fire not per case, so relatively cheap
	Robotic vessel sealer	Great for pedicle work in pT3 patients, low thermal spread, jaws do not get as hot
	Cadiere forceps	Low grip strength, excellent if attempting intracorporeal diversion
	Double fenestrated grasper	Also low grip strength for use on bowel, large surface area so helpful for retracting redundant sigmoid or large, floppy bladder
	Robotic stapler	Si only has 45-mm nonvascular loads, however Xi has 45-mm and 30-mm loads and has green, blue, and white available
Suture		
	3-0 or 4-0 Prolene; precut 6 in.	Ready to fix vascular injuries if occur
	4-0 or 5-0 chromic; precut 6 in.	For ureteral stent fixation if performing ICUD
	Silk suture (full length) tied to X-Large Hem-o-lok clips	For ureteral tagging, full length allows them to reach all the way out of port so easy to identify w/ mini lap incision for extracorporeal diversion
Female Cases		
	V Care uterine manipulator	Aids mobilization of uterus by assistant, with better definition of colpotomy and maintenance of pneumoperitoneum

Table 36.3 Robotic Cystectomy Safety Checklist

Item	Definition	Failure	System Check
Patient properly secured	Patient in appropriate predetermined position and secured to bed to prevent slippage during Trendelenberg	Patient not secure and slips during prolonged Trendelenburg causing injury/delay. Straps too tight causing injury	Check patient after positioning but before prepping in steep Trendelenburg to confirm no slippage. Anesthesia and surgical team confirm padding not too tight
Faulty equipment check	Equipment needed for case checked ahead of time. TilePro is functional if desired, robot preliminary check occurs	System delays for troubleshooting while patient under anesthesia	Check any equipment needed for case that can be checked ahead of time
Robot docked correctly	Placement of robot is done so that robotic arms are optimized for specific case	Si and Xi systems have different docking characteristics. Failure of team/provider to recognize could lead to injury/delay or increased conversion rate	Team/provider and trainees well versed and review differences in docking between systems
Instruments ready for easy exchange	Instruments needed in urgent and routine situations should be unbundled to improve efficiency	Inability to access instruments quickly may delay procedure and cause patient harm	Operating room setup designed to allow commonly used instruments to be set out for easy exchange
Equipment issues reported	Any issue during the case w/ robotic-specific equipment reported so as to prevent issues arising in next case	Failure to do so could cause delays as instruments at end of life reprocessed and put back in trays for next case also at increased cost	Checklist at end of procedure includes reporting of issues to appropriate personnel and checking "lives" on instruments

(Adapted from Ahmed K, Khan SA, Hayn MH, et al. Analysis of intracorporeal compared with extracorporeal urinary diversion after robot-assisted radical cystectomy: results from the International Robotic Cystectomy Consortium. Eur Urol 2014;65:340-7.)

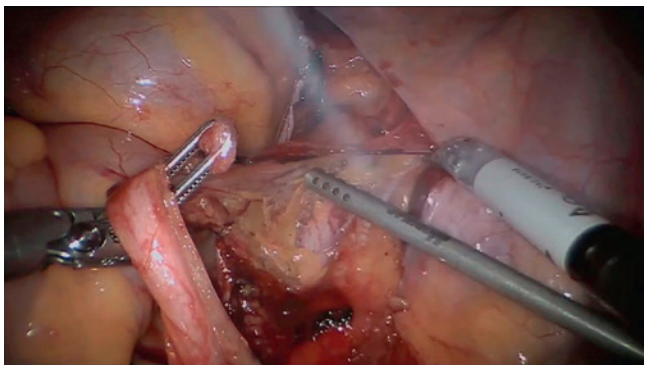


Figure 36.1 Right ureter with preserved adventitia during ureteral dissection of robot-assisted radical cystectomy.

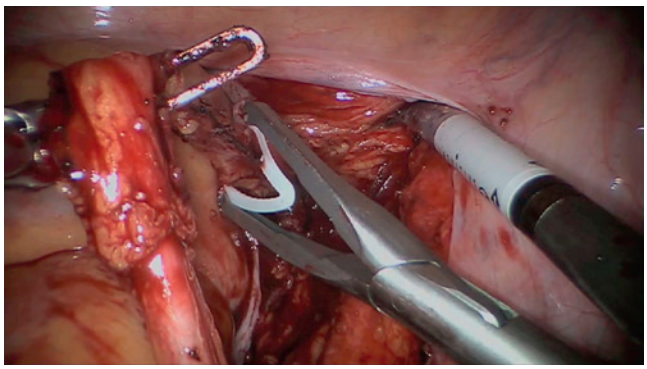


Figure 36.2 Right ureter with clips and stitch identification during distal transection of the ureter near the bladder.

as cephalad as possible to ease visualization of the proximal common iliac artery dissection. We mobilize the ureter cephalad to this point, but no higher, in order to preserve blood supply. Careful handling of the ureter is vital during this dissection, and therefore the ureter should not be grasped directly nor should an inordinate amount of tension be placed either using the fourth arm or by the assistant during dissection. Preserving periureteral fat adjacent to the ureter preserves adventitial blood supply and avoids subsequent ureteral stricture (Fig. 36.1). During the ureteral dissection, identification of the left ureter can be challenging, especially in obese patients. To facilitate dissection in these challenging cases, the medial leaflet of the posterior peritoneum should be skeletonized just lateral to the sigmoid colon and the rectum. This technique often reveals the ureter within the fatty tissue. The double fenestrated grasper (i.e., ProGrasp) can be helpful during this dissection if the fourth arm is on the patient's right side, since its large surface area can retract a redundant sigmoid colon.

During distal dissection of the ureter, the surgeon will begin to encounter the anterior bladder pedicle, which often will demonstrate lateral branches from the superior vesical artery supplying the distal ureter. At this point, clipping the ureter with a large Hem-o-lok with full-length suture attached will aid in later identification of the ureter if attempting extracorporeal diversion (Fig. 36.2). Prior to transection, a distal clip placed on the bladder side of the ureter can guide the surgeon when performing pedicle ligation to prevent inadvertent bladder entry.

As a final point of caution, we advise careful and judicious use of monopolar and bipolar cautery during ureteral dissection. By lowering Bovie settings to 25W/25W for cut and coagulation, inadvertent thermal injury can be avoided. The surgeon must be mindful of both lateral thermal spread as well as jaw temperature profiles of the vessel sealing devices. The degree of lateral thermal spread varies with device type, power setting, and application time. Monopolar cautery has the highest temperature and highest degree of

thermal spread.[38] Estimates for the EndoWrist One vessel sealer are a lateral thermal spread of only 1–2 mm, consistent with the LigaSure.[39]

POSTERIOR DISSECTION AND PEDICLES

Many surgeons elect to perform the lymph node dissection first. However, performing posterior dissection immediately after ureteral mobilization and transection may be preferable for those early in their learning curve. Early posterior dissection tends to be a natural progression for surgeons with experience in the posterior approach to robotic prostatectomy. Once the ureters are dissected distally to the level of the bladder, the incision can be extended horizontally across the posterior peritoneum at the reflection of the peritoneal edge. The dissection plane can then be elaborated posterior to the rectovesical fascia, just superficial to the anterior wall of the rectum, ensuring an adequate margin of tissue posteriorly. To avoid inadvertent rectal injury when moving anteriorly, dissection should be performed as distally as possible. If the 30-degree lens is being used, switching to 30 degrees up will often allow dissection to the prostatic apex. These maneuvers will establish the rectal plane as well as the medial aspect of the vascular pedicle.

A common error that can occur early in the learning curve is early bladder release. Releasing the anterior bladder attachments prior to the posterior dissection can make this step significantly more challenging as tension is paramount to preventing rectal injury. We typically employ the assistant for tension at the peritoneal reflection by pulling posteriorly and slightly cephalad to produce tension on the rectum while the robotic fourth arm pulls up on the posterior bladder wall.

Just as thermal energy is important with ureteral dissection, heat must also be considered carefully during the posterior dissection. Temperature and thermal spread can be minimized by employing the benefits of the EndoWrist One vessel sealer. Studies in porcine models demonstrate burst pressures well above three times systolic blood pressure ranges on vessels up to 7 mm in diameter using this device.[39] The vessel sealer can therefore be used to perform the entire bladder pedicle dissection as well as prostate pedicle if so desired with minimal thermal spread. Alternatively, the vessel sealer can be used to the level of the endopelvic fascia, followed by Hem-o-lok clips for the prostate pedicle with athermal ligation (Fig. 36.3A). Other tools utilized for the vascular pedicles can include clips, the LigaSure device, or staple fire via either the robotic tool or laparoscopic stapler. If using a laparoscopic stapler, it is important to note the length of the shaft. The laparoscopic stapler we typically use has a 440-mm shaft, which facilitates reach into the deep pelvis (Fig. 36.3B). This stapler should be used cautiously when early in the learning curve, as it requires a larger, more accurate dissection plane and careful articulation to prevent positive margin or rectal injury.

If a rectal injury occurs during RARC, it tends to occur during the posterior dissection and pedicle ligation. Although rectal injury is rare, the injury is often recognized intraoperatively and can be repaired robotically in many cases. Rectal repair should initially involve clear delineation of the edges of the defect and an assessment of the mechanism of injury. If thermal injury is suspected, the surgeon must consider debriding the defect back to the healthy bleeding bowel to ensure apposition of edges that are free from injury. The American Association of the Surgery of Trauma (AAST) has a rectal injury grading scale (RIS) used for the management of rectal injury during trauma (Table 36.4). AAST recommendations include primary repair of RIS I to III injuries. The authors recommended a single primary closure using 3-0 monofilament absorbable suture

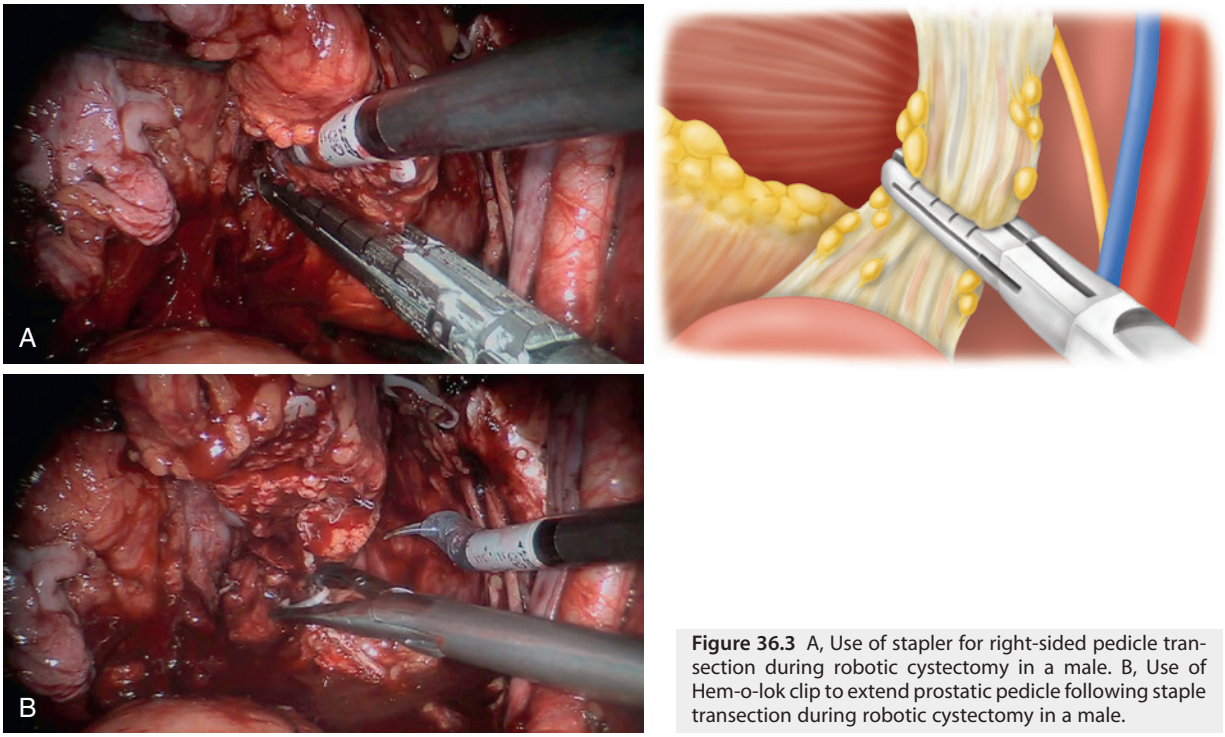


Figure 36.3 A, Use of stapler for right-sided pedicle transection during robotic cystectomy in a male. B, Use of Hem-o-lok clip to extend prostatic pedicle following staple transection during robotic cystectomy in a male.

Table 36.4 American Association of the Surgery of Trauma (AAST) Rectal Injury Grading Scale (RIS)

Grade		Description
I	Hematoma	Contusion or hematoma without devascularization
	Laceration	Partial thickness, no perforation
II	Laceration	<50% circumference
III	Laceration	>50% circumference
IV	Laceration	Full thickness with extension into the perineum
V	Vascular	Devascularized segment

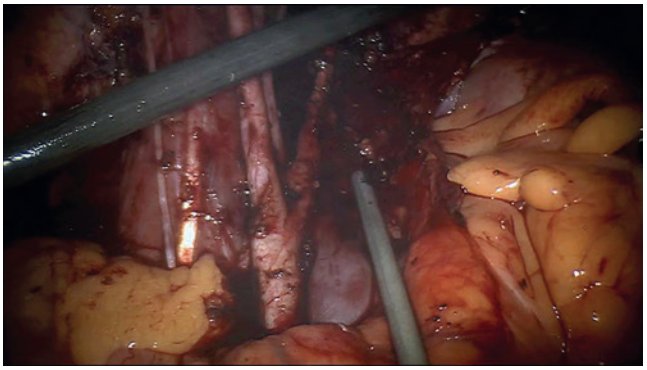


Figure 36.4 Completed robotic extended lymph node dissection.

and did not recommend placement of a drain in the deep pelvis as it is unnecessary and may increase the risk for fistula.[12] Patients in this cohort had not undergone bowel preparation; if contamination is not significant, a primary repair can be performed and diversion is often not required. Similar recommendations have been made within the urologic and gynecologic literature, emphasizing primary two-layered repair with interrupted suture without the need for diverting colostomy.[40,41] Our institutions have used a 3-0 V-Loc simple running suture in these rare instances with excellent result. Following repair, we recommend testing the repair by filling the pelvis with fluid from the suction irrigator and performing an air enema with a catheter or proctoscope.

DEVELOPING SPACE OF RETZIUS AND PROSTATE DISSECTION

When finished with the posterior dissection, the bladder can be released from the anterior abdominal wall. Utilizing the 30-degree up lens can be helpful early in the learning curve to aid visualization of the urachus. The new Xi robot can facilitate a quick switch using the console, but changing the lens angle may not warrant the additional time necessary to switch lenses using older versions of the robot. During this portion of the operation, careful attention to incorporating the perivesical fat is important to avoid a positive margin. On the other hand, if peritoneal mobilization is too wide after release of the medial umbilical ligaments, the inferior epigastric vessels can also be injured. Inferior epigastric vessel injury can be easily prevented with adequate traction by the robotic fourth arm or assistant. If inadvertent injury occurs, simple ligation of the vessel is sufficient with thermal energy.

The remainder of the anterior dissection follows closely the approach used for robotic prostatectomy. One important difference is careful dissection of the urethra to the level of the catheter. If performing neobladder, we advise limiting cautery and maximizing urethral length. Once the catheter is encountered, an extra-large Hem-o-lok clip can be placed across the catheter and cut distally. The cut catheter can then be used for cephalad retraction to mobilize the remainder of the posterior attachments. During the remaining dissection, careful attention to any residual rectal attachments should be noted to avoid thermal injury or rectal perforation.

LYMPH NODE DISSECTION

The Pasadena Consensus Panel (PCP) has laid out recommendations for the extent of lymph node dissection for robotic cystectomy, which involves, at minimum, nodes up to the bifurcation of the common iliac vessels, lateral to the genitofemoral nerve, including nodes of the lateral wall of the bladder to the lateral pelvic sidewall, and extending distally to the femoral canal. All nodes above and below the obturator nerve should also be removed. Common iliac nodes and presacral nodes were not agreed upon as standard but optional and certainly possible via the robotic approach (Fig. 36.4).[37] This portion of the operation involves several different structures that are commonly at risk for injury.

Typically, the dissection begins by focusing on the lateral margin of the dissection. Dissecting down to the psoas fascia and over to the lateral arterial edge helps early identification and preservation of the genitofemoral nerve. If the genitofemoral nerve is inadvertently transected, repair is difficult due to its small size and is not recommended due to its lesser relevance as a sensory nerve only. The anterior surface of the external iliac artery has no branches for the majority of its course, but as dissection proceeds distally, the deep circumflex vein will cross over the anterior surface of the artery, which is at risk for injury. If injury of the circumflex vein occurs, simple ligation is warranted.

Following anterior and lateral dissection, dissection proceeds posterior to the artery. At this point, we will dissect posterior to the artery in order to free the lymphatic tissue from the muscle and the posterior wall of the external iliac vessels. If the psoas muscle is identified and followed posteriorly, the posterolateral lymphatic attachments can be easily removed while maintaining excellent vascular control deep in the recess between the external and internal branches, also known as the space of Marseille (Fig. 36.5). By using this approach, the external iliac vein can be carefully observed and obturator dissection of the lymph node packet is better facilitated.

However, the obturator nerve can be injured from this posterior approach if one is not familiar with this viewpoint, and can also be injured during release of the medial lymphatic tissue. To avoid injury, identification of the obturator nerve prior to ligation is preferred. Additional caution should be exercised when using monopolar cautery near the nerve as it can conduct the current and stimulate the

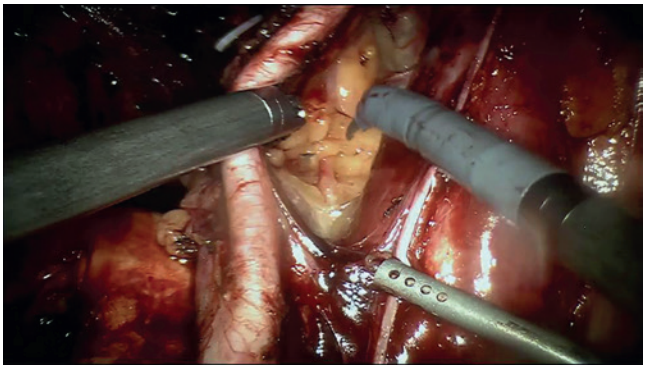


Figure 36.5 Posterolateral lymph node dissection in the space of Marseille.

nerve. If using electrocautery, we advise lowering energy to 25W/25W for cut and coagulation to minimize lateral thermal spread, similarly to what is performed during ureteral dissection. Preferably, the bipolar or vessel sealer better minimizes thermal spread and nerve conduction. If the obturator nerve is injured as a partial transection, repair should be performed immediately in all cases. Simple 5-0 interrupted monofilament sutures should suffice, but some surgeons prefer 4-0 or 6-0 suture. Every attempt should be made to place the suture in the epineurium to reapproximate the nerve ends. In the case of a full-thickness transection in which the ends can be brought together in a tensionless fashion, primary realignment should be performed in a similar fashion to that described above. If the ends cannot be approximated in a tensionless fashion, then a sural nerve graft can be used.[42]

Vascular injury occurs most often during lymph node dissection while performing RARC. A recent review examined major vascular injuries during nonvascular surgery and found that 63% of injuries occurred during cancer surgery, with urologic cases demonstrating the highest frequency at 29.6%.[43] The majority of reported injuries were partial laceration, and the vessel most commonly injured was the iliac vessel. In the majority of cases, primary repair was used, and injury-related complications did not occur.[43] The iliac artery is often easier to repair, but the iliac vein is more commonly at risk due to difficulty in appreciating the vein edges secondary to steep Trendelenburg and pneumoperitoneum. If the surgeon is prepared with robotic instruments and precut Prolene suture, repair can be relatively straightforward.

The initial phase of vascular injury repair requires hemorrhage control. Grip strength of the robotic instruments must be considered, as some tools can cause significant damage to blood vessels if used to grasp them. Mini lap sponges should be on the field in anticipation of this possible complication to apply direct pressure at the site of bleeding without concern for further injury with the robotic instruments. If the surgeon is able to apply direct pressure to the injury to control bleeding, then removing their head from the console will lock the arms in place and hold pressure while the team organizes materials needed for the repair. If blood loss is significant but currently controlled with pressure, communication with anesthesia is essential to ensure that the patient can tolerate additional blood loss before a repair attempt is made. If the injury is isolated with adequate control in a stable patient, robotic repair may be attempted. The method of injury should be determined. If a full-thickness thermal injury occurs to a large artery or vein, involvement of a vascular surgeon should be strongly considered given the requirement for proximal and distal control, debridement, and more complex repair. If the fourth arm has the double fenestrated grasper or a similar instrument with low grip strength, it may be used to directly grasp the vessel while suture is delivered to the robotic surgeon and the instruments are quickly exchanged to needle drivers. If the laceration causes bleeding that impedes vision, a small laparoscopic bulldog clamp can be used to obtain temporary proximal and distal control. Finally, injury to the internal iliac artery can be ligated without serious consequence in the majority of cases. If the repair can be performed with simple suture, then it may be attempted; otherwise, ligation is acceptable.

ISSUES UNIQUE TO FEMALE CYSTECTOMY

If a hysterectomy is to be performed, the VCare uterine manipulator can be an excellent tool to aid in mobilization of the uterus by the assistant during the hysterectomy portion of the procedure. The uterine manipulator also provides the surgeon with better definition of where the colpotomy should be performed. If utilizing the AirSeal inflation system, pneumoperitoneum will be maintained. However, if the inflation system is unavailable, the uterine manipulator can aid in maintaining pneumoperitoneum while the vaginal incision is closed.

The bladder neck and urethral dissection are different in the female patient, and inadvertent entry into the bladder or anterior vaginal wall can occur if the surgeon is not cautious during posterior dissection. If the uterine manipulator is not used, a lubricated sponge-stick can fill the potential space of the vagina and ease identification of its borders during dissection. Once these vaginal borders are identified, the pedicles become apparent and can be ligated in a similar fashion to that of male cystectomy (Figs. 36.6A, B). When elaborating the plane between the bladder and vagina, erring on the side of the vagina is always recommended to avoid inadvertent bladder entry. Any vaginotomy must then be closed carefully, and the remaining urethral stump should also be closed to prevent persistent urethral or vaginal drainage. Rarely, persistent leakage may require a repeat procedure but often will resolve with time. To aid in appropriate healing of the vaginal incision, we recommend estrogen-soaked gauze be put in place immediately after the procedure and removed the following day. In addition, topical estrogen treatments for the first 2 weeks can aid healing.

URINARY DIVERSION

Many of the complications associated with RARC are associated with the urinary diversion. Although many robotic surgeons perform the diversion extracorporeally, the intracorporeal approach (ICUD) is another option. Regardless of robotic approach, diversion type also greatly impacts complication rates, with studies suggesting a higher complication rate among patients undergoing neobladder or Indiana pouch compared to ileal conduit.[21] Regardless of approach, the left ureter should be tunneled prior to undocking the

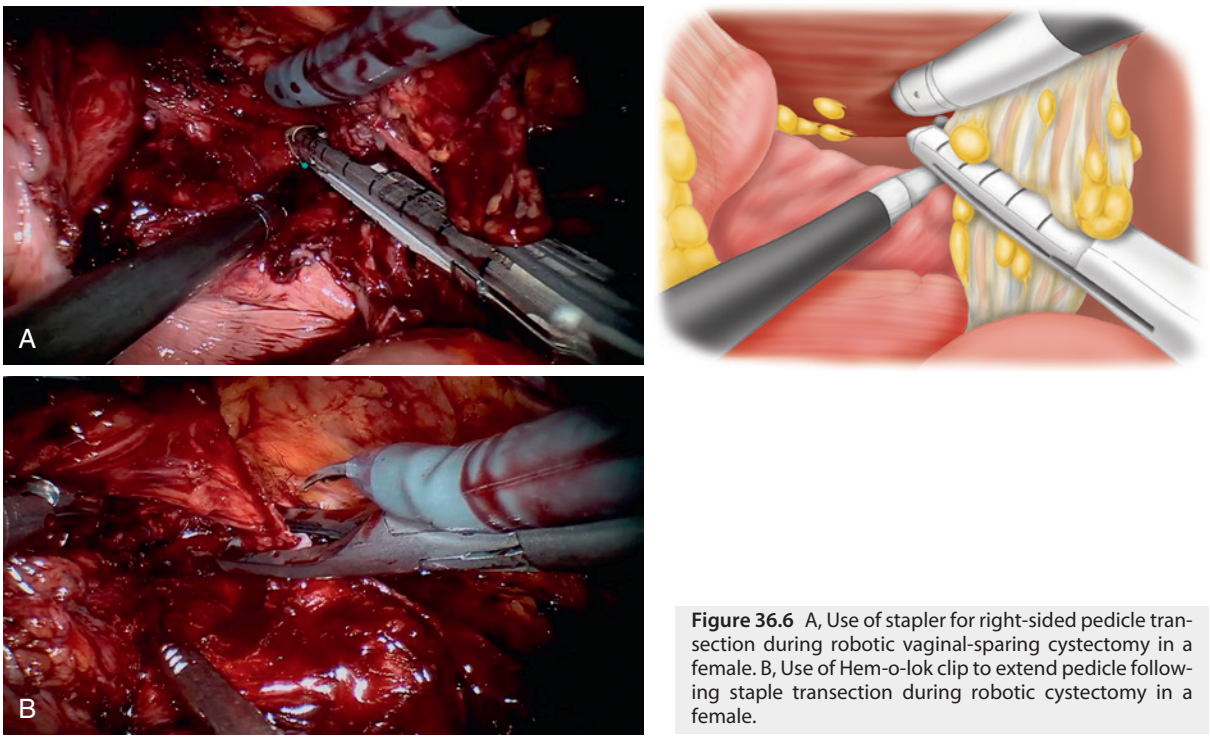


Figure 36.6 A, Use of stapler for right-sided pedicle transection during robotic vaginal-sparing cystectomy in a female. B, Use of Hem-o-lok clip to extend pedicle following staple transection during robotic cystectomy in a female.

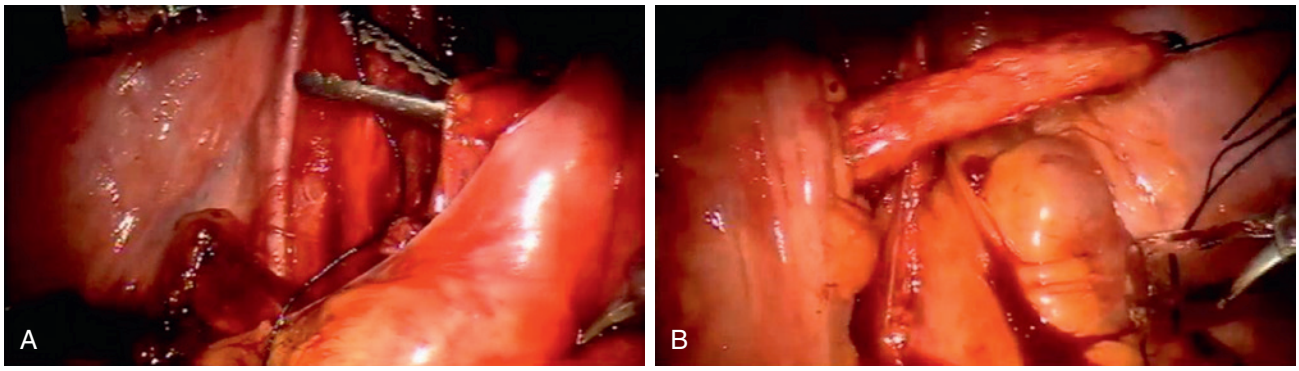


Figure 36.7 A, Grasping the left ureteral suture to tunnel under the sigmoid mesentery. B, The left ureter has been successfully tunneled to the right side, facilitating extracorporeal (or intracorporeal) urinary diversion.

robot as this can be challenging to perform extracorporeally through a small incision. A locking grasper can be placed in the right assistant port (or the undocked right robotic arm) and placed across to the left side. The grasper can then carefully secure the long suture attached to the ureter (Fig. 36.7A) and carefully direct the ureter to the right side (Fig. 36.7B). The extracorporeal diversion can then be performed similarly to an open procedure. For the purposes of this chapter, we will focus the remainder of this section on the robotic intracorporeal urinary diversion.

Intracorporeal ileal conduit is now commonly performed among robotic surgeons. When attempting to transition from extracorporeal to intracorporeal diversion, an additional port near the pubic symphysis can allow easy access and angulation for the stapler when handling the bowel anastomosis as well as performing the Wallace plate for the ureters. By using the long stay sutures on the ureters (as described in the ureteral dissection section), the ureters can be placed on slight tension by bringing these sutures through the additional port and positioning them for easy sewing. Another simple modification is the marionette stitch, which is passed through the abdominal wall on a Keith needle, through the distal end of the bowel segment, and back through the abdominal wall (untied). The marionette stitch allows movement of the conduit, aids in manipulation during the bowel portion, and facilitates positioning of the end of the conduit and the ureters for ureteroenteric anastomosis.[36] When performing the bowel resection, we recommend that the bowel be cut obliquely to remove more of the antimesenteric bowel wall, especially in situations of poor mesenteric circulation.

Intracorporeal neobladder (ICNB) can also be performed, but can be challenging when first embarking on this approach. We recommend reducing Trendelenburg, which can facilitate dropping of the neobladder toward the urethra stump. Confirming adequate mesenteric length to allow neobladder reach to the urethra should be performed prior to bowel resection. Traction loops placed through windows on the mesenteric side of the bowel can also be helpful when determining adequate length and is preferred over traction sutures in the bowel

wall, which can cause damage. The Van Velthoven technique of performing the neourethral anastomosis prior to stapling off the bowel segments can allow easy transition to ICNB for the robotic surgeon. We prefer two V-Lock sutures, with their ends tied, similar to robotic prostatectomy anastomotic suture. The most common intraoperative complication during ICNB is inability to obtain a watertight anastomosis. In order to adequately space sutures, we recommend stay sutures every 5–7 cm before attempting to close the posterior wall. The anterior wall can then be closed in a modified U-pouch configuration leaving a gap at the cephalad-most extent for the afferent ileal chimney. This allows for passage of the stents up the ureters, which are typically connected in a Wallace technique. The remaining hole is closed around the stents, which are brought out through the anterior abdominal wall and placed to an ostomy pouch in the immediate postoperative setting.

We recommend ureteral stents following both diversion types to aid in healing and prevent urine leak. An external stay suture using 5-0 chromic can prevent the stents from inadvertent removal. If considering ICUD, we recommend mastery of the robotic extirpative portion first to minimize operative time and time-related complications.

Postoperative Complications and Management

VENOUS THROMBOEMBOLISM

Inherent to the risks of radical cystectomy for malignancy is postoperative deep venous thrombosis (DVT) and/or pulmonary embolism. Contemporary ORC series approximate thromboembolic risk as 1–4% of all complications.[3,44,45] A retrospective study using data from the National Surgical Quality Improvement Program evaluated 1307 patients undergoing cystectomy from 2005 to 2011. Approximately 6% of patients were diagnosed with venous thromboembolism (VTE), with a mean time to diagnosis of 15 days postoperatively.[46] Among patients diagnosed with VTE, 55% were diagnosed following discharge, and 30-day mortality from VTE was 6% in this series. Specific risk factors associated with VTE included advanced age, longer operative time, and history of sepsis. Another large study using claims data from the Marketscan database extended analysis through 90 days to determine VTE risk following cystectomy. Among 1581 patients undergoing cystectomy, 10% were diagnosed with a VTE within 90 days of cystectomy (3.8% within 30 days after discharge, and 3.3% between 31 and 90 days after discharge). Risk factors associated with VTE risk included orthotopic neobladder urinary diversion, discharge to a skilled nursing facility, and prolonged index hospital stay following cystectomy.[47]

While these studies provide a broad overview of the high risk of venous thromboembolism, coding constraints preclude the ability to determine the impact of surgical approach on VTE risk (and compare RARC to ORC). Additional risk factors that may increase the rate of DVT/thromboembolism following RARC may be related to Trendelenberg, dorsal lithotomy positioning, and prolonged pneumoperitoneum.[48] To determine if RARC does carry an increased risk of VTE, a randomized clinical trial from Memorial Sloan Kettering compared 118 RARC and ORC patients. No differences were noted in thromboembolic complications (8.3% and 8.6%, respectively).[12]

To determine if extracorporeal or intracorporeal diversion impacted hematologic risk, an analysis from the International Robotic Cystectomy Consortium evaluated 935 patients undergoing RARC with pelvic lymph node dissection across 18 international centers between 2003 and 2011. Among 768 patients undergoing extracorporeal and 167 patients undergoing intracorporeal diversion, no differences were noted among preoperative variables such as age, sex, BMI, and preoperative chemotherapy. Additionally, no difference was noted in hematologic complications between extracorporeal (9%) and intracorporeal (10%) conduits.[28] However, hematologic complications included bleeding along with venous thromboembolism risk, with no specific mention made of specific DVT or VTE risk.

Despite no appreciable added VTE risk of RARC over ORC, VTE risk remains high following cystectomy regardless of approach. To better outline the need for VTE prophylaxis, the American Urological Association (AUA) Best Practice Statement for prevention of DVT in patients undergoing urologic surgery emphasizes risk stratification of patients based on both surgery type and patient risk factors (Table 36.5). Given that the majority of patients undergoing RARC are >40 years old with multiple risk factors (e.g., cancer, chemotherapy, smoking), routine DVT prophylaxis is common practice at our institutions. Each patient is provided a dose of low-molecular subcutaneous heparin in the hour before

Table 36.5 Risk Factors for Deep Vein Thrombosis

Surgery
Obesity
Smoking
Varicose veins
Ventral venous catheterization
Trauma
Immobility, paresis
Malignancy
Oncologic therapy (e.g., chemotherapy, radiotherapy, hormonal)
Prior deep vein thrombosis
Increased age
Estrogen-containing oral contraception/hormone replacement therapy
Selective estrogen receptor modulators
Acute medical illness
Heart or respiratory failure
Inflammatory bowel disease
Nephrotic syndrome
Myeloproliferative disorders
Paroxysmal nocturnal hemoglobinuria
Inherited or acquired thrombophilia

(*From Geerts, W.H., Pineo, G.F., Heit, J.A., et al.: Prevention of venous thromboembolism. Chest 2004; 126(3): 338S-400S.)

anesthesia induction, and lower extremity compression devices are activated before the patient is positioned and throughout the hospital course. As has been pointed out in prior studies, at least half of venous thromboembolic events occur in the postdischarge setting. Enoxaparin prophylaxis for 4 weeks after surgical treatment of abdominal or pelvic cancer both is safe and significantly decreases the incidence of thrombosis, as compared with 1-week prophylaxis.[49] Therefore we routinely provide extended enoxaparin prophylaxis to prevent VTE as a complication following RARC for 4 weeks following discharge.

WOUND INFECTION/FASCIAL DEHISCENCE

Wound infection and dehiscence are not uncommon complications following the traditional ORC approach, and while many of these can be managed conservatively, some require reoperation and prolonged hospitalization.[50,51] The incidence of wound infection after ORC is approximately 3–6%, but can be higher in some series, with dehiscence risk much lower at 1–3%.[44,52] A single institution study from Japan evaluated surgical site infections following ORC. Predictors of infection included increased age, thick subcutaneous fat, and absence of a subcutaneous closed-suction drain (in obese patients), which has reduced the risk of subsequent surgical site infection. While this has not been studied in RARC, it could be considered for those patients with larger incisions and extracorporeal diversions.[53]

In comparison to ORC, the incidence of wound infection following RARC appears to be lower, with most robotic series reporting a wound infection rate of 1%. In a randomized clinical trial that compared ORC to RARC, overall infectious complications were not significantly different between RARC (38%) and ORC (29%) ($p = 0.3$). However, wound infection was significantly lower in RARC (3.3%) compared to ORC (14%) ($p = 0.04$).[12]

Risk factors for surgical site infections and dehiscence include a host of factors, including prior smoking history, diabetes, cardiopulmonary disease, and malnutrition.[54–58] Furthermore, elevated blood loss with associated hypovolemia can diminish tissue oxygenation, thereby impacting wound healing by compromising tissue integrity.[59–61] As RARC has been demonstrated to have lower blood loss compared to ORC series, this may contribute to the lower wound infection rates noted in many series. Regardless of approach, we attempt to minimize surgical site infections by using standard preoperative antibiotic prophylaxis (<24 hours) and ensuring a negative urine culture prior to surgery.

LYMPHOCELE

Given that pelvic lymph node dissection is an integral part of RARC for bladder cancer, lymphocele is a potential complication following surgery. In ORC series, the incidence of lymphocele approximated 1–4%, with the majority being self-limited.[62,63] Very few studies have investigated lymphocele as a complication following RARC. In a single institution study evaluating early complications following RARC among 50 patients, only one lymphocele was noted (2%) and treated successfully with percutaneous drainage.[64] In another single institution study investigating complications among RARC with intracorporeal neobladders, the overall lymphocele rate was 5/70 (7%) with 1.4% experiencing no symptoms (and treated conservatively) and the remaining four patients (6%) treated with drainage due to accompanying symptoms.[65] These data suggest that lymphocele rates of RARC are comparable to that of ORC and can likely be treated similarly.

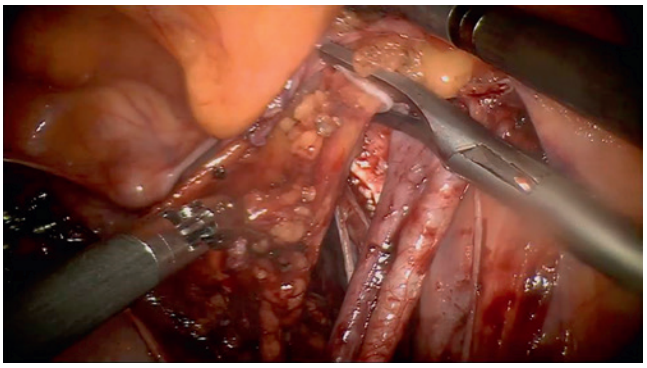


Figure 36.8 Use of Hem-o-lok clip during lymph node dissection to prevent subsequent lymphocele.

Debate between the merits of standard versus extended pelvic lymph node dissection (PLND) is ongoing. While standard PLND is defined by boundaries comprising common iliac bifurcation (cephalad), circumflex iliac vein (distal), genitofemoral nerve (lateral), and hypogastric vessels (posterior, including the obturator fossa), extended PLND also includes nodes to the bifurcation of the aorta as well as the presacral nodes anterior to the sacral promontory.[66] A study of 92 consecutive patients undergoing ORC evenly divided them into standard and extended lymphadenectomy groups, and no differences in 30-day major or minor complications were noted.[67] We encourage meticulous clipping of lymphatic vessels during RARC PLND (either with a titanium clip applier or Hem-o-lok clips as needed) to minimize the subsequent risk of lymphocele formation (Fig. 36.8).

Symptomatic patients may experience ileus, fever, abdominal pain, lower-extremity edema, and gastrointestinal symptoms from mass effect on adjacent organs. Compression of pelvic veins by the lymphocele can also increase the risk of thromboembolic events.[68,69] Diagnosis can be confirmed by radiologic imaging. Ultrasonography might reveal an anechoic cystic structure that may contain thin septations or debris, while computed tomography (CT) often demonstrates a thin-walled hypodense lesion with negative Hounsfield units. A thickened wall with enhancement on CT may indicate an infected lymphocele.

Should lymphocele develop, which has been rare in our experience, most appear to be self-limited. If the patient is experiencing symptoms (either in the form of pain, infected lymphocele, or compression against the vessels), we have found that a simple drain placement will resolve the majority of cases. Should this also fail, additional maneuvers include instillation of sclerosing agents or laparoscopic marsupialization of the lymphocele.[70,71] If the lymphocele is large, fluid obtained by percutaneous aspiration should be evaluated for bacterial culture and analysis of creatinine to exclude urine leak. Success rates with drainage alone approximate 80%, with many only requiring a few days to a week to resolve.[68]

ILEUS

Postoperative ileus, defined as a delay in coordinated movements of the gastrointestinal tract, is a common complication following radical cystectomy, whether performed in an open or robotic manner. The pathophysiologic causes of postoperative ileus are multifactorial and are more common after bowel surgery. Several causes of ileus include inhibitory neural reflexes related to bowel manipulation as well as a large host of neurotransmitters and inflammatory factors that include nitric oxide (an important mediator of initial paralysis) and increased mucosal permeability due to several peptides such as substance P and vasoactive intestinal peptide.[72] Postoperative ileus has been found to be one of the leading causes of prolonged hospital stay following cystectomy.[73]

While historic ORC series approximate prolonged ileus at 15–20%, RARC ileus rates appear to be similar in some series and lower in others. In a single institution study of 104 ORC and 35 RARC patients, ileus rate was similar among RARC and ORC patients (26% vs 30%, respectively).[74] Another single institution study found that ileus rates after RARC were 4/50 (8%).[64] A larger study of 209 consecutive patients undergoing RARC found an overall ileus rate of 22%, with a similar rate between extracorporeal conduit or orthotopic diversion.[21] In a single study investigating complications among RARC with intracorporeal neobladders, the rate of ileus was only 6% (n = 4/70). Among these 4 patients, two were treated conservatively, one was treated with a small intestine enema, and one obstructive ileus was treated with a reoperation.[65]

Regardless of the cystectomy approach, ileus rates have improved with the addition of enhanced recovery protocols in surgery.[3,44] A recent review of enhanced recovery protocols in robotic cystectomy surgery demonstrated that enhanced recovery programs can reduce postoperative ileus and may include preoperative nutritional optimization, the absence of bowel preparation, carbohydrate loading, minimization of narcotic usage, and a structured plan for dietary advancement in the postoperative setting.[75] Additional maneuvers that can reduce ileus among RARC patients include the use of alvimopan. A multicenter randomized controlled trial in which 143 patients were randomized to alvimopan and 137 to placebo demonstrated significantly lower postoperative ileus-related morbidity (8.4% vs 29.1%, respectively; $p < 0.001$).[76]

Intraoperative care can also reduce ileus rates. Epidural anesthesia can reduce the need for opiates, but has additional side effects such as vasodilation, postural hypotension, and reducing mobility. An alternative is the inclusion of rectus sheath catheters, which can directly deliver pain control to the incision.[77]

If prolonged ileus occurs despite preventative measures following RARC, treatment is similar to traditional approaches for ORC. Careful correction of electrolyte imbalances can help restore bowel function, and additional causes should be entertained (including the possibility of intraabdominal abscess or urinoma, which can cause a generalized peritonitis). If ileus continues, we recommend bowel decompression using a nasogastric tube to control nausea and vomiting and to better delineate resolution of ileus. If the nasogastric tube is placed, repletion of output is necessary to maintain fluid status. For those cases not responding to conservative measures, small bowel obstruction must be investigated with further imaging as indicated.

ANASTOMOTIC LEAK AND ENTEROCUTANEOUS FISTULA

Although rare, additional postoperative gastrointestinal complications following radical cystectomy include both anastomotic leak as well as enterocutaneous fistula. Most retrospective studies reveal no differences between ORC and RARC gastrointestinal complications, but no specific comment regarding bowel leak or fistula. In a large cohort of over 800 patients undergoing either RARC with extracorporeal or intracorporeal diversion, gastrointestinal complications occurred in 20% of patients but at a lower rate in the intracorporeal group (10% vs 23%; $p < 0.001$).[28] However, these complications were not stratified by type (e.g., ileus versus anastomotic leak or enterocutaneous fistula). Similarly, a randomized controlled trial from Memorial Sloan Kettering revealed no significant differences in overall GI complications between RARC and ORC (23% vs 29%, respectively), although again no specific details on types of GI complications were recorded. In one single institution study that did specify types of GI complications among 35 RARC and 104 ORC cases, overall GI complications were similar.[74] No cases of enterocutaneous fistula, bowel leak, or rectal injury were reported.

Additional research is needed to determine the risk of anastomotic leak and enterocutaneous fistula following RARC with or without intracorporeal diversion, but likely these rates remain low, given the low rates in the existing literature.

Conclusions

Although RARC is a relatively new procedure, the number of cases are growing and many surgeons are adopting the technique. Complication rates appear to be largely similar to the open approach, with minor variations based on intraoperative challenges, patient positioning, and incisional differences. This chapter reviewed the common complications that occur in the RARC perioperative period as well as methods to avoid these complications. A clear understanding of each complication's presentation, prevention, and treatment can ensure success early in the surgeon's learning curve.

Although complications are common following RARC, many perioperative complications can be avoided through adequate preparation. A thorough understanding of the RARC technique as well as adherence to perioperative pathways, appropriate equipment, and institutional support can successfully minimize complications following RARC.

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Chapter 36 Questions

1. During robotic cystectomy, which portion of the case is at most risk for vascular injury?
   a. Lymph node dissection
   b. Urinary diversion
   c. Posterior dissection
   d. Anterior dissection
   e. All of the above (all have equal risk)

2. Which maneuver(s) can assist intracorporeal diversion and avoid complications?
   a. Robotic fourth arm placed on the patient's left side
   b. Removing 15–20 degrees of steep Trendelenberg
   c. Stay sutures every 5–7 cm during neobladder construction
   d. Marionette stitch
   e. All of the above

3. During ureteral dissection, which factor does NOT lead to complications of ureteral stricture?
   a. Hem-o-lok clip of the distal ureter when transecting
   b. Use of monopolar cautery in close proximity to the ureter
   c. Tension of the ureter during dissection
   d. Manipulation of the ureter by grasping with robotic instruments
   e. None of the above

4. During dissection of the ureter or posterior dissection, which instruments/thermal settings cause the most thermal spread?
   a. EndoWrist One vessel sealer
   b. Bipolar device
   c. Monopolar scissors
   d. Ligasure
   e. None of the above cause thermal spread

5. A patient undergoes robotic cystectomy, and during posterior dissection, a rectal laceration is noted. The injury appears to be <50% circumference and did not involve cautery. What is the grade and recommended treatment for this injury?
   a. II / primary repair
   b. III / colostomy
   c. II / colostomy
   d. III / primary repair
   e. I / primary repair

6. After robotic cystectomy with bilateral pelvic lymph node dissection, your patient returns with fever and unilateral lower extremity edema. Imaging demonstrates a large left fluid collection with negative Hounsfield units and a thickened, enhanced wall. What is your next step in treatment?
   a. Chemotherapy for recurrent disease
   b. Drain placement and antibiotics
   c. Observation
   d. Instillation of sclerosing agent into the fluid collection
   e. None of the above

7. Which complications are decreased in robotic cystectomy as compared to traditional open cystectomy?
   a. Deep venous thrombosis
   b. Lymphocele
   c. Wound infection
   d. None of the above
   e. All of the above

8. When performing a female cystectomy with hysterectomy, what tool(s) can be helpful to perform colpotomy?
   a. Lubricated spongestick in the vagina
   b. VCare uterine manipulator
   c. Insufflation of the vagina
   d. All of the above
   e. a or b

9. During a challenging pelvic lymph node dissection, you are using monopolar cautery. Suddenly, profuse bleeding is encountered at the level of the iliac vein. What is your next best step in management?
   a. Using mini lap sponges, apply direct pressure at site of bleeding
   b. Grasp the vein directly with the ProGrasp
   c. Consult vascular surgery
   d. Change instruments to needle drivers
   e. a and c

10. During robotic cystectomy port placement, what considerations can ensure success during the procedure?
    a. Camera port placed at least two fingerbreadths above the umbilicus
    b. Robotic fourth arm placed on the patient's left if considering intracorporeal neobladder and using robotic stapler
    c. Robotic fourth arm placed on the patient's left if considering intracorporeal neobladder and using laparoscopic stapler
    d. a and b
    e. a and c

Case Studies

CASE 1

A 69-year-old male presents to your office for evaluation of gross hematuria. Transurethral resection of bladder tumor confirms urothelial carcinoma present in the lamina propria and muscularis propria, and a staging CT chest, abdomen, pelvis is obtained that shows left hydroureteronephrosis (Case Fig. 36.1). No lymphadenopathy is noted.

1. What is the stage based on CT imaging and clinical history?
   a. cT1N0
   b. cT2N0
   c. cT3N0
   d. cT4N0
   e. None of the above

2. Based on the above diagnosis and stage, the patient is offered neoadjuvant chemotherapy and returns to



Case Figure 36.1

your clinic for discussion of surgery. Repeat staging CT is obtained that reveals no lymphadenopathy and similar bladder findings as prechemotherapy CT. What options do you offer him?

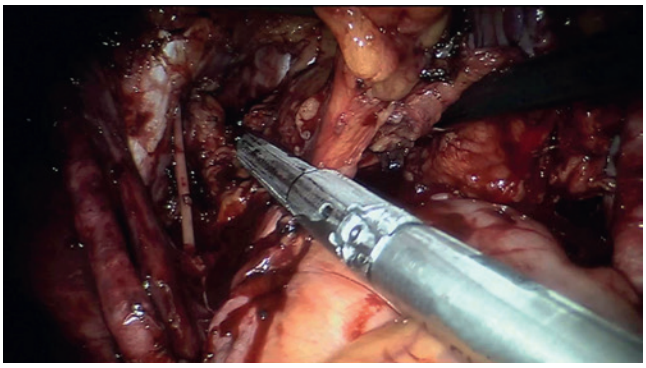
a. Open radical cystoprostatectomy
b. Robotic radical cystoprostatectomy
c. Partial cystoprostatectomy
d. a or b
e. All of the above

3. The patient opts for robotic radical cystoprostatectomy. During the right pelvic lymph node dissection, the obturator nerve is partially transected. What is the next acceptable step in management of this complication?
   a. Full-thickness interrupted monofilament 5-0 sutures to reapproximate the nerve
   b. Conservative management (no primary repair)
   c. Interrupted monofilament 5-0 sutures to reapproximate the nerve, with sutures in epineurium only
   d. Sural nerve graft
   e. Staple nerve ends together

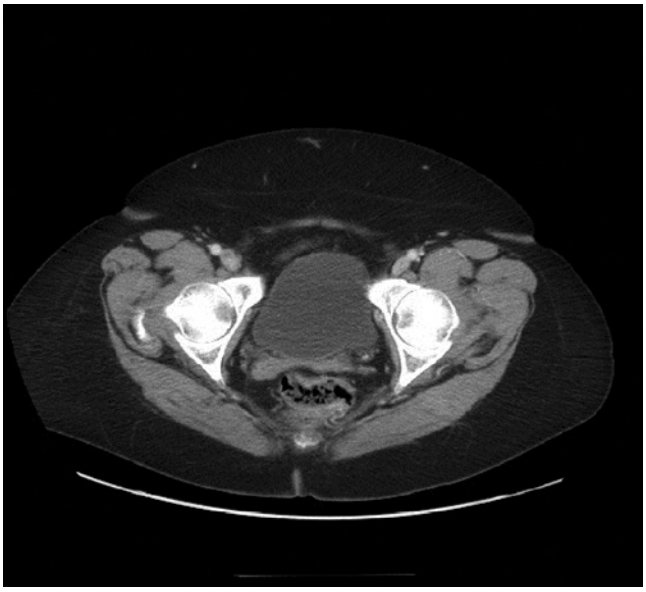
4. Following the lymph node dissection, the posterior dissection proceeds. You experience some difficulty in the right side of this dissection. A stapler is placed to take this pedicle as shown in Case Fig. 36.2. Following the staple load, a small amount of brown fluid is noted, indicating a rectal laceration. You estimate this to be a small tear. What is the next step in management?
   a. Freshen the edges of the rectal laceration
   b. Perform primary closure with a running monofilament suture
   c. Leave a drain at the site of closure
   d. All of the above
   e. a and b

CASE 2

A 60-year-old female presents to you with stage II muscle-invasive bladder cancer. She is interested in robotic



Case Figure 36.2

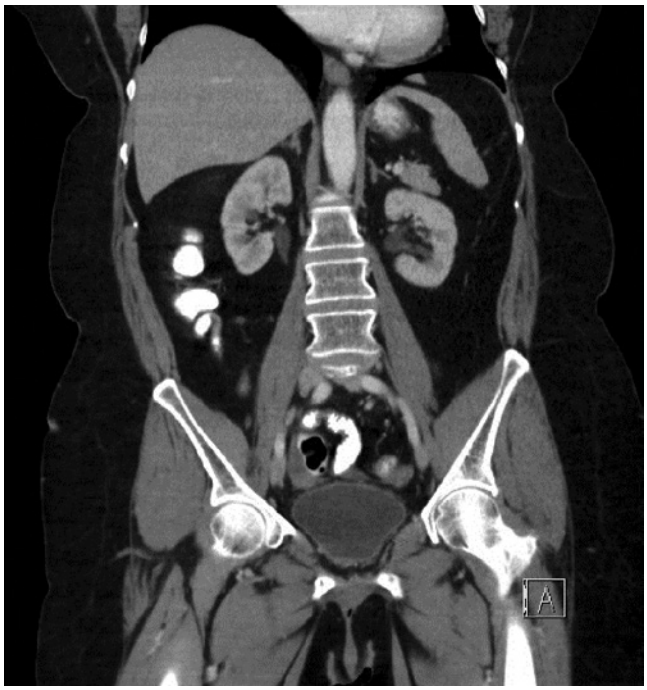


Case Figure 36.3

cystectomy with intracorporeal neobladder. She is sexually active and wishes to preserve the ability for intercourse following the procedure. She is continent, with no complaints of stress urinary incontinence. Her CT scan is demonstrated in Case Figs. 36.3 and 36.4.

1. What is the best surgical approach based on her disease and preferences?
   a. Robotic cystectomy with vaginal-sparing, intracorporeal neobladder
   b. Robotic cystectomy with non–vaginal sparing, intracorporeal neobladder
   c. Robotic cystectomy with vaginal-sparing, extracorporeal neobladder
   d. Robotic cystectomy with non–vaginal sparing, extracorporeal neobladder
   e. None of the above; the patient is not a candidate for robotic cystectomy

2. As you begin the posterior dissection, the uterus obscures your view, and you have difficulty identifying the location to begin your colpotomy. What is the best next step to assist with this?
   a. Insufflate the vagina
   b. Spongestick placed in the vagina



Case Figure 36.4

c. VCare uterine manipulator
d. All of the above
e. b and c

3. As you proceed with posterior dissection between the vagina and bladder, you find the plane to be somewhat difficult. What options are indicated in this case?
   a. Abort vaginal-sparing procedure and perform anterior vaginectomy
   b. Continue dissection closer to the vaginal wall, and abort if this plane remains challenging
   c. Continue dissection in this plane, as this plane is always challenging
   d. a or b
   e. None of the above

4. You are now ready to begin your intracorporeal neobladder. As you are early in the learning curve, you would like to maximize your chances of success. What maneuvers can be helpful in performing this procedure?
   a. Reduce Trendelenburg positioning by 15–20 degrees
   b. Place a marionette stitch
   c. Perform the Van Velthoven technique of performing the neourethral anastomosis before stapling the bowel segments
   d. Place assistant port on patient's left side to facilitate use of the stapler without undue tension on the mesentery
   e. All of the above

Answers

1. **a.** During the lymph node dissection, the surgeon is removing lymph nodes that are adherent to the external iliac artery and vein, internal iliac artery and vein, and the common iliac artery and vein.

Case Table 36.1 American Association of the Surgery of Trauma (AAST) Rectal Injury Grading Scale (RIS)

Grade		Description
I	Hematoma	Contusion or hematoma without devascularization
	Laceration	Partial thickness, no perforation
II	Laceration	<50% circumference
III	Laceration	>50% circumference
IV	Laceration	Full thickness with extension into the perineum
V	Vascular	Devascularized segment

2. **e.** Placement of the robotic fourth arm on the left side allows the surgeon to more easily manipulate the robotic stapler if desired and manipulate the bowel more easily. Removing 15–20 degrees of steep Trendelenberg will take some of the tension off of the small bowel and allow it to more easily mobilize into the pelvis, which is the most appropriate working space based on the original robotic setup for the case. Stay sutures will allow you to more easily keep the neobladder aligned while sewing it closed in order to get a water tight closure. The marionette stitch can aid in movement of the bowel segment so as to make the ureteral anastomosis easier.
3. **a.** Monopolar cautery will cause more spread with the current used and cause unintentional damage to the surrounding tissue such as the ureter. The anastomosis should be tensionless and handled with care during the dissection. Manipulating the ureter by grasping with robotic instruments is not appropriate in most situations as the grip strength for the robotic instruments is greater than the surgeon realizes, causing crush injury to the ureter.
4. **c.** The monopolar devices in general cause greater thermal spread than bipolar devices.
5. **a.** Please refer to Case Table 36.1. For a grade II laceration, primary repair is the operative step of choice.
6. **b.** Signs of infected lymphocele include fever and imaging consistent with abscess (rim-enhancing fluid collection). While asymptomatic lymphoceles can be managed conservatively, infected lymphoceles require drainage and antibiotics.
7. **c.** Randomized trials comparing open and robotic cystectomy confirm similar complication rates between techniques. However, a recent trial from Memorial Sloan Kettering demonstrated an increase in wound complications (such as wound infection) with open cystectomy (14%) compared to robotic cystectomy (3%).
8. **e.** The VCare uterine manipulator can aid in mobilizing the uterus by better defining the appropriate location where colpotomy should be performed. Similarly, a lubricated spongestick in the vagina can serve the same purpose.
9. **e.** An iliac vein injury secondary to cautery may be more extensive than initially appreciated. Just as in open surgery, your first step should include direct pressure applied at the site of bleeding while simultaneously consulting vascular surgery. Mobilizing this

resource may avoid catastrophic blood loss in this challenging situation. Once you have control (which includes mobilizing blood products as needed), you may wish to attempt repair on your own (changing instruments to needle drivers). However, be cautious in attempting this during challenging lymph node dissections in which the vein is not yet fully exposed. Vascular surgery consults can prove very useful in these situations.

10. **e.** Camera port placement at least two fingerbreadths above the umbilicus facilitates lymph node dissection and intracorporeal bowel work. Furthermore, the robotic fourth arm should be placed on the left if considering intracorporeal neobladder (and using a robotic stapler), which minimizes tension on the bowel during staple fire. If using a laparoscopic stapler, the robotic fourth arm should be placed on the patient's right to allow the assistant to approach the anastomosis from the left.

CASE 1

1. **c.** The patient has apparent invasion of tumor into the perivesical fat near the left ureteral orifice. This finding, combined with left hydroureteronephrosis, suggests clinical T3 disease.
2. **d.** Robotic and open radical cystoprostatectomy are both viable options for this patient. Several research studies confirm that robotic cystectomy can be safely carried out by experienced surgeons with similar oncologic efficacy to that of open surgery. However, for inexperienced robotic surgeons, beginning with less challenging cases would be prudent before considering robotic cystectomy for challenging stage III cases.
3. **c.** Robotic repair of obturator nerve injuries can be successfully performed similarly to open surgery. In fact, use of the robotic instruments can allow for finer control of the anastomosis. Using an interrupted monofilament 5-0 suture can reapproximate the nerve and often avoid postoperative sequelae.
4. **e.** When encountering minimal spillage in a patient without risk factors of wound healing (e.g., prior pelvic radiation), a small rectal laceration can be successfully repaired primarily by freshening the edges of the laceration and performing primary closure with a running monofilament suture. Depending on surrounding and available tissue, a two- to three-layer closure is preferred. Drain placement is needed; however, this should not be placed at the site of closure to avoid undue pressure on the anastomosis, which may prevent wound healing.

CASE 2

1. **a.** Given the patient's interest in preserving sexual function and CT demonstrating no obvious bulky tumor posteriorly, a vaginal-sparing approach is appropriate. The patient is also a candidate for intracorporeal neobladder, and without any obvious contraindications, this procedure should be offered.
2. **e.** In cases in which the uterus obscures view, either a VCare uterine manipulator or (more simply) a vaginal spongestick can provide better visualization when performing the colpotomy.
3. **d.** One must use caution when noting difficulty in the dissection plane between vagina and bladder, as it may indicate tumor in this area. Before aborting a vaginal-sparing approach, dissection may be continued closer to the vagina (to err on the side of vaginotomy rather than cystotomy). However, if dissection remains difficult, the surgeon should perform anterior vaginectomy rather than compromise margin status.
4. **e.** Several maneuvers can ensure intracorporeal neobladder success. These include lessening Trendelenburg by 15–20 degrees to assist with bowel manipulation. Additionally, a marionette stitch can be helpful as can the Van Velthoven technique of performing the neourethral anastomosis before stapling bowel segments. Finally, ensuring that the assistant port is placed on the patient's left side will facilitate use of the stapler without creating mesenteric tension.

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SECTION VII

Complications of Extirpative Surgery

37 Complications of Nephrectomy

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CHAPTER OUTLINE

Preoperative Considerations
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Urologic Considerations
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Special Populations
Tumor Thrombus
Cytoreductive Nephrectomy
Locally Recurrent Disease
Donor Nephrectomy
Elderly Patients
Transitional Cell Carcinoma
Chapter 37 Questions and Answers

KEY POINTS

1. Advantages of anterior incisions, whether midline, subcostal, or chevron, include quick exposure to the renal pedicle and the great vessels.
2. Up to 23% of patients will have a flank sag postoperatively as a result of injury to intercostal nerves that causes laxity of flank muscles at that level.
3. In cases anticipated to have a difficult hilar dissection or anterior approach, in which anatomic access to the artery is more difficult, preoperative renal artery embolization may be helpful.
4. The most common cause of splenic injury is excessive traction on the splenic attachments that rips the splenic capsule.
5. In cases of pancreatic injury, if injury of the duct is noted, distal pancreatectomy is the preferred method of management.
6. If bleeding makes repair of liver injury difficult, total obstruction of hepatic vascular inflow may be obtained by Pringle maneuver.
7. Perioperative strategies to decrease complication rates in elderly patients include minimal operative time, earlier consideration of blood transfusions, and possible gastric tube placement to decrease pneumonia rates.

Surgical removal of the kidney was reported as early as 1861. However, the first planned nephrectomy was probably performed by Gustav Simon in 1869 for a ureterovaginal fistula.[1] Because early nephrectomies were associated with high mortality rates as a result of peritonitis, the flank incision became the preferred approach until the 1950s, when effective antibiotic prophylaxis was developed. In 1969, Robson and colleagues published a seminal article describing their surgical management of renal tumors through the thoracoabdominal approach. Early control of the renal vessels, en bloc excision of kidney and adrenal with Gerota's fascia remaining intact, and extended lymphadenectomy allowed improved survival compared with simple nephrectomy.[2]

The principles outlined by Robson and associates still form the basis for treatment of similar tumors. Since that time, however, advances in imaging techniques have improved detection of smaller lesions and have caused a significant downward stage migration. This change may partially account for improvements in the morbidity and mortality of nephrectomy. Evolving surgical techniques, including laparoscopy and robotic surgery, anesthesia improvements, newer antibiotics, and effective intensive care contribute as well. Contemporary open nephrectomy is likely reserved for larger or more complex lesions thereby, possibly increasing complication risk.

Preoperative Considerations

CARDIOPULMONARY CONSIDERATIONS

Some possible life-threatening cardiopulmonary complications common to all surgical procedures include hypovolemic shock, myocardial infarction, pneumonia, pulmonary embolism, and pulmonary insufficiency. Renal surgery may cause severe stress to the cardiopulmonary system through many etiologies, including patient positioning effects and blood loss. The slow-growing nature of most renal neoplasms allows time for preoperative cardiopulmonary optimization, including the possibility of coronary or carotid artery revascularization. This must be balanced against the anticoagulation typically initiated after these interventions.

Patients undergoing nephrectomy frequently are placed in the flank position for surgical access. This position may severely stress the cardiopulmonary system, especially if the operating table is broken or a kidney rest is extended. First, pressure on the great vessels may decrease preload and increase afterload, thereby decreasing cardiac output. Second, ventilation is limited by the flank position. In addition to limiting the excursion of the dependent diaphragm, increased ventilation–perfusion mismatching may further decrease oxygen exchange and lead to hypoxia. These combined cardiopulmonary effects may make this position intolerable for some patients with limited reserve.

These issues necessitate careful preoperative screening of patients for pulmonary diseases and cardiac status. Cardiology and pulmonology consultation should be obtained if any doubt exists about the patient's condition. Preventive measures instituted preoperatively and invasive monitoring intraoperatively may increase safety for some patients. The potential for blood loss and large hemodynamic shifts should prompt preoperative blood typing. In addition, autologous blood donation should be offered to patients.

UROLOGIC CONSIDERATIONS

Preoperative workup of the urinary tract should include imaging of the operative site, with a specific focus on localized extent of tumor burden, effect on nearby visceral structures, presence or absence of tumor thrombus, and vascular anatomy. Physicians should include assessment of contralateral kidney function in addition to total kidney function. Urinalysis and, if indicated, urine culture and sensitivity should be performed to ensure urinary tract sterility before the planned operation. If urinary tract infection is found, antibiotics with adequate coverage should be given.

PATIENT PREPARATION

General intraoperative preventive measures are very important in avoiding complications common to any surgical procedure. Strict adherence to evidence-based recommendations ensures best possible outcomes. Antibiotic prophylaxis should be initiated ≥30 minutes before incision. Two large-bore intravenous access ports must be in place, and there should be consideration of arterial pressure monitoring and central venous access prior to the procedure. Per the 2008 AUA guidelines on the "Prevention of Deep Vein Thrombosis in Patients Undergoing Urologic Surgery," subcutaneous heparin should be initiated preoperatively to decrease the risk of deep vein thrombosis. Alternatively, compression hose, or preferably sequential compression devices, should be placed on the lower extremities unless contraindications such as open ulcers exist.[3] If this is the case, some evidence suggests that placement of these devices on the arms may still provide some antithrombotic effects. The patient must be positioned carefully with pressure points sufficiently padded. Factors pertaining to specific positions are discussed later.

GENERAL MEDICO-RENAL CONSIDERATIONS

Nephrectomy represents the removal of an important component of the body's mechanism for maintaining blood pressure homeostasis. The incidence of postoperative hypertension is <8%, usually mild, and it frequently resolves.[4] In the long term, hypertension develops in some kidney donors, but it is not significantly different from hypertension in matched population controls or siblings.[5]

Postoperative acute renal insufficiency may be multifactorial, relating to removal of a large percentage of the body's functional nephrons, direct or indirect manipulation of the contralateral kidney that causes arterial spasm, and rhabdomyolysis related to patient positioning. Postoperative acute renal insufficiency is usually transient but may require dialysis in some cases.

In the long-term, radical nephrectomy has been shown to be associated with the development of renal insufficiency, and this should be considered in all patients undergoing nephrectomy, even in the presence of a normal contralateral kidney.[6]

Surgical Approach

Many incisions have been described for nephrectomy. These may be classified into anterior, flank, and posterior approaches. Indications for specific incisions include patient body habitus, size and location of the renal lesion, other concurrently planned operations, indications for lymphadenectomy, and surgeon experience.

SITE VERIFICATION

The Joint Commission (formerly the Joint Commission on Accreditation of Healthcare Organizations) reported

Table 37.1 WHO Surgical Checklist

Before Induction of Anaesthesia	Before Skin Incision	Before Patient Leaves Operating Room
Sign In	**Time Out**	**Sign Out**
Patient has confirmed: ☐ Identity ☐ Site ☐ Procedure ☐ Consent	☐ **Confirm all team members have introduced themselves by name and role**	**Nurse verbally confirms with team:** ☐ The name of the procedure recorded ☐ That instrument, sponge and needle counts are correct (or not applicable ☐ How the specimen is labeled (including patient first name) ☐ Whether there are any equipment problems to be addressed
☐ **Site marked/not applicable**	**Surgeon, anesthesia professional and nurse verbally confirm:** ☐ Patient ☐ Site ☐ Procedure	☐ **Surgeon, anesthesia professional and nurse review the key concerns for recovery and management of this patient**
☐ **Anesthesia safety check completed**	**Anticipated critical events**	
☐ **Pulse oximeter on patient and functioning**	**Surgeon reviews:** ☐ What are the critical or unexpected steps, operative duration, anticipated blood loss?	
Does the patient have a:	**Anesthesia team reviews:** ☐ Are there any patient-specific concerns?	
Known allergy? ☐ No ☐ Yes	**Nursing team reviews:** ☐ Has sterility (including indicator results) been confirmed? ☐ Are there equipment issues or any concerns?	
Difficult airway/aspiration risk? ☐ No ☐ Yes, and equipment/assistance available	**Has antibiotic prophylaxis been given within the last 60 minutes?** ☐ Yes ☐ Not applicable	
Risk of >500 mL blood loss (7 mL/kg in children)? ☐ No ☐ Yes, and adequate intravenous access and fluids planned	**Is essential imaging displayed?** ☐ Yes ☐ Not applicable	

(Adapted from Mahajan RP. The WHO surgical checklist. Best Pract Res Clin Anaesthesiol. 2011;25:161-8.)

statistics on wrong-site surgery and showed that the incidence was increasing, peaking in 2011 at 152 reported events. However, since that time, there has been a continued decrease in reported events; 67 events were reported in 2014.[7] Approximately 10% of cases are reported to be urologic. A review of 7147 sentinel events reported to the AJCC between 2005 and 2010 revealed that 956 events, or 13.4%, were due to wrong-site surgery. In 2011, the World Health Organization published the surgical checklist which helps ensure the reduction of wrong-site surgery (Table 37.1).[8] Rigorous adherence to policies designed to prevent these occurrences is necessary to optimize patient care.

ANTERIOR INCISIONS

A main advantage of anterior incisions, whether midline, subcostal, or chevron (Fig. 37.1), is quick exposure to the renal pedicle and the great vessels. This feature may not be as important for prevention of tumor seeding as was first thought, but ease of exposure and familiarity with anatomy is still advantageous. Other situations that would favor the anterior approach include procedures in trauma patients, patients who cannot tolerate flank approach positioning, planned bilateral nephrectomy in patients with polycystic kidney disease, large or upper pole tumors, bilateral renal neoplasms, left nephrectomy with significant thrombus extension into the vena cava, and other preoperative indications for bilateral dissection. Although rarely indicated because of the accuracy of modern imaging techniques, the anterior approach also allows exploration of the abdomen for metastatic disease. Some investigators advocate extended lymphadenectomy with nephrectomy, and this procedure is easiest through an anterior approach.

The disadvantages of anterior approaches include transection of multiple muscle groups for subcostal or chevron incisions. If the operation is performed transperitoneally, any spillage of tumor or infectious material may have greater consequences than if the material is confined to the retroperitoneum. If the operation is intended to be retroperitoneal, anterior approaches may not be best because entry into the peritoneal cavity may accidentally occur. Transperitoneal operations are associated with formation

of adhesions and possible future small bowel obstruction. This complication was estimated to occur in 2% of patients in some series.[9] Obese patients may not be suitable candidates for anterior approaches because of difficulties associated with excessive extraperitoneal and intraperitoneal fat.

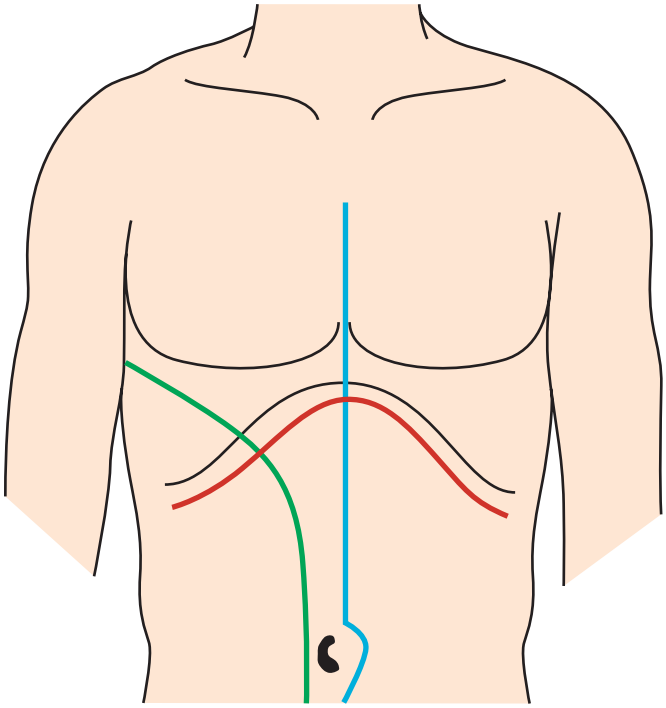


Figure 37.1 Diagram demonstrating anterior incisions. Midline incisions (blue) may be extended superiorly if exposure of the thoracic vena cava is necessary. The subcostal incision (red) may be extended across the midline if a complete chevron incision is necessary. A thoracoabdominal incision (green) offers excellent exposure to the superior renal pole and thoracic vena cava.

FLANK INCISIONS

Flank approaches may be preferable for uncomplicated nephrectomies. This approach allows access to the retroperitoneum while avoiding entry into the peritoneum or chest. Careful attention must be given to positioning and padding of the patient. Taping the hips too tightly to the operating table can result in gluteal necrosis. The incision may be accomplished in the 10th or 11th interspaces, or the 10th, 11th, or 12th ribs may be resected. If an intercostal incision is performed, the incision should be made immediately superior to the rib to avoid damage to the neurovascular bundle that runs immediately below each rib and is between the internal oblique and transversalis muscle layers. Up to 23% of patients have a flank sag postoperatively as a result of injury to intercostal nerves that causes laxity of flank muscles at that level (Fig. 37.2).[10] This condition may be difficult to distinguish from a true hernia, which is a rarer complication requiring surgical treatment to prevent incarceration. Poor nutritional status, diabetes, and other risk factors for poor wound healing predispose to the risk of hernia formation. Computed tomography (CT) imaging aids in establishing the diagnosis of an incisional hernia. Postoperative pain from flank incisions may be significant, especially during deep inspiration. Pain may become a long-term problem as a result of neuritis or entrapment of an intercostal nerve in the sutures or surrounding scar tissue. This complication may be prevented by careful reapproximation of the muscle layers. Fortunately, these issues usually resolve with time. Reassurance may be all that is required, but some patients require local steroid injections for analgesia.

THORACOABDOMINAL INCISIONS

The thoracoabdominal incision is a large incision now usually reserved for large or complicated radical nephrectomies. The extensive incision allows exploration of the

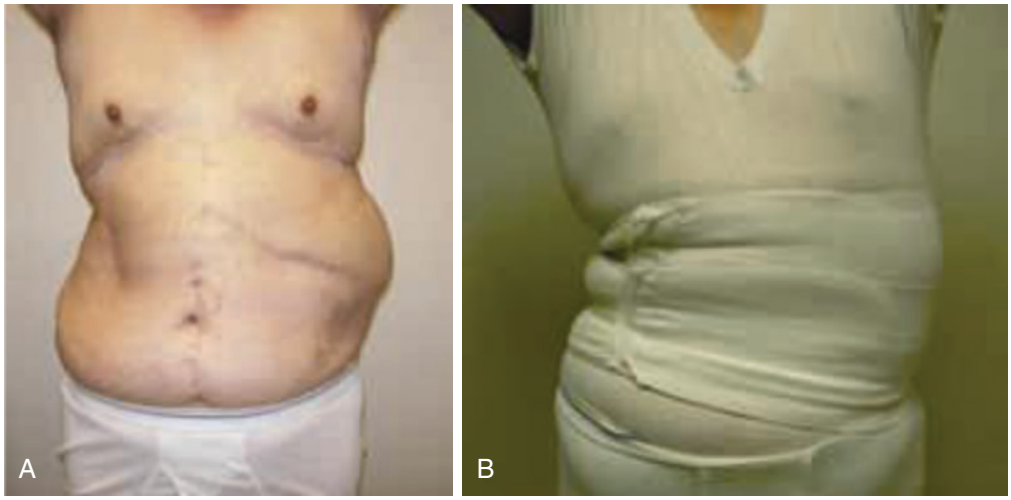


Figure 37.2 A, This patient is a 63-year-old man who underwent left splenectomy through a midline incision secondary to lymphoma and nephrectomy through a flank incision for T3b renal cell carcinoma (RCC). Although the surgical margins were negative, two sequential RCC recurrences of the diaphragm and renal bed were resected through a subcostal incision. Despite subsequent repair of a flank incisional hernia, the patient continues to have flank laxity, in part because of transected intercostal nerves. B, Photograph showing management of flank laxity with an abdominal binder.

peritoneal, retroperitoneal, and thoracic compartments with biopsy or wedge resection of any suspicious lesions. The exposure to the upper pole of the kidney is excellent, and therefore this incision may be used when an extensive upper pole lesion is anticipated. Vena cava thrombi with known extension above the diaphragm or into the right atrium may require entry into the thoracic cavity, and a right thoracoabdominal incision provides good visualization of the thoracic vena cava and right atrium. The disadvantage of this incision is the considerable morbidity associated with it. The size of the incision predisposes it to infection and significant postoperative discomfort. Spillage of tumor or infectious particles may be problematic given that both the peritoneum and the thoracic cavity are affected. Caution must be exercised when the left thoracoabdominal incision is used, to avoid injury to the spleen during incision of the diaphragm. The division of the costal cartilages anteriorly may lead to significant postoperative pain if these cartilages are not fixed securely with nonabsorbable suture. Rare complications include postoperative hemidiaphragmatic paralysis from division of the phrenic nerve and an annoying clicking sensation from nonunion of the costal cartilages.[11]

LUMBODORSAL INCISIONS

A distinct advantage of lumbodorsal incisions is decreased postoperative pain. This incision allows entry into the retroperitoneal space without division of any muscle groups and thereby minimizes the surgical trauma, which is one cause of postoperative discomfort of patients. Wound breakdown is uncommon with lumbodorsal incisions because the only layer to be divided, the lumbodorsal fascia, is very strong. The disadvantages of this incision center on the limited exposure it provides. Because extensive dissection of the vascular pedicle is very difficult, this incision is inadequate for renovascular surgery and radical nephrectomies with large tumors, upper pole disease, or suspected tumor extension or tumor thrombus. Division of the costovertebral ligament of the 12th rib may improve upper pole exposure. However, this maneuver risks damage to the costal neurovascular bundle. Because of the limited exposure provided by lumbodorsal incisions, they are less commonly used than are anterior or flank approaches. At present, laparoscopic surgery has widely replaced the lumbodorsal approach to minimize incision size and postoperative pain.

Intraoperative Complications

HEMORRHAGE

Angiography is not routinely performed before nephrectomy. Thus, prevention of significant intraoperative hemorrhage requires accurate knowledge of renal anatomy and blood supply as well as the variations commonly encountered.

Arterial Anatomy

In the majority of patients, a single renal artery branches laterally off the aorta and enters the renal hilum. On the right, the renal artery usually courses posterior to the vena cava. Multiple renal arteries are not uncommon, seen in >25% of patients in some series.[12] These arteries, if present on the right, generally pass anterior to the vena cava. The renal arteries are end circulation. If the artery or any of its branches is occluded, ischemic infarction of the kidney or the respective segment will occur.

Because the gonadal artery, adrenal artery, and inferior phrenic artery also lie in close proximity to the areas of dissection, these vessels are vulnerable to injury. The inferior phrenic arteries are the first abdominal branches of the aorta and generally have branches coursing inferior to supply a portion of the adrenal circulation. The adrenal arteries branch from the aorta at the level of the celiac trunk anteriorly and course laterally to the adrenals. Additional adrenal arterial branches frequently originate from the renal artery. The gonadal arteries branch laterally off the aorta below the renal arteries. Alternatively, they may occasionally branch off the renal artery. The right gonadal artery most often passes anterior to the vena cava.

Venous Anatomy

Venous drainage of the kidney, in contrast to the arterial circulation, has many collateral vessels. The right renal vein drains directly into the vena cava, usually without major branches. The left renal vein is usually joined by the left gonadal vein, left adrenal, and a lumbar vein before it passes anterior to the aorta to join the vena cava. Both renal veins generally lie anterior to the corresponding renal artery. Multiple renal veins are less common than are multiple arteries but they do occur in approximately 1% of patients, generally on the left. The renal vein may divide, with one limb anterior and one posterior to the aorta. Alternatively, only the posterior branch may remain.[13] The extensive collateral vessels of the renal venous system prevent slowly occurring occlusive processes such as tumor thrombus formation from causing kidney damage, renal failure, or other symptoms. Because of the greater collateral circulation on the left, the left renal vein may be ligated acutely with probable survival of the renal unit. The right lacks such extensive collateral vessels.

Statistics of Hemorrhage

Radical nephrectomy has classically been considered a bloody surgical procedure. Neovascularization and additional collateral circulation to renal tumors can be extensive. In historical series, most patients required transfusions with the average amount reaching 2 L.[2] More modern series report an average blood loss of 300 mL and a transfusion rate of only 15%.[14] Hemorrhage during nephrectomy for neoplastic conditions is more likely compared with benign conditions.[15] Close attention to surgical technique may minimize complications associated with hypotension, anemia, and blood transfusion. Adequate venous access must be ensured preoperatively to allow rapid resuscitation and possible blood transfusion.

Preoperative Embolization

Preoperative embolization is an attractive option when tumor extent makes extensive vascularity probable (Fig. 37.3). Infarction of the entire kidney should theoretically reduce blood loss, although most studies have not found this to be the case.[16,17] Some surgeons believe that embolization

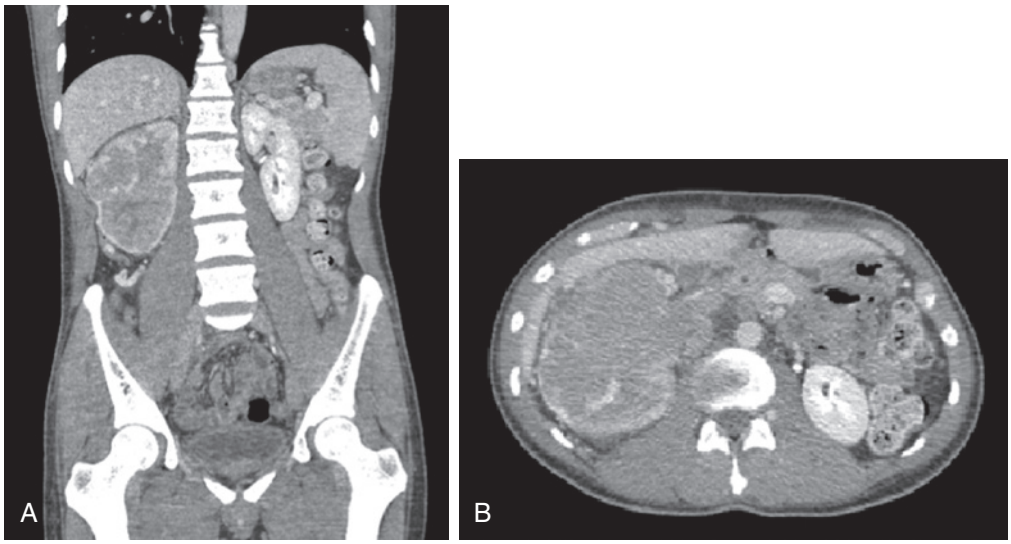


Figure 37.3 This 26-year-old man had a T3a tumor that was managed with preoperative embolization. A, Coronal view and B, Axial view.

may allow easier dissection of the kidney because it forms an edematous plane immediately surrounding the infarcted tissue. Arterial embolization also allows earlier ligation of the renal vein. In cases anticipated to have a difficult hilar dissection or anterior approaches, in which the anatomic access to the artery is more difficult, angioinfarction may be helpful. Examples include patients with large hilar tumors overlying the artery, bulky nodal disease encasing the artery, or bulky venous thrombus. Early ligation of the vein or mobilization of the kidney itself may allow better-visualized division of the renal artery.

In patients with tumor thrombus (discussed later), embolization may cause some regression in the extent of the thrombus.[18] More importantly, in the case of an occluded renal vein, it may allow early division of the collateral venous drainage that encircles the kidney in the perinephric fat. This technique may allow much easier surgical approach and dissection. Although it is not routinely necessary, preoperative embolization may assist in management of large, hypervascular tumors.

Common complications of embolization include the *embolization syndrome* consisting of nausea, vomiting, fever, and flank pain. Nephrectomy should be carried out ≤48 hours after embolization to minimize these symptoms. Another alternative is placement of a thoracic epidural catheter before embolization, a strategy we routinely employ. Embolization contributes to postoperative ileus. Thus, some degree of bowel preparation or a clear liquid diet preoperatively may by useful. More serious complications include acute renal failure, which may be exacerbated by accidental embolization of the contralateral kidney through reflux of the embolizing agent. Accidental embolization of other organs also occasionally occurs and causes serious complications such as heart failure and spinal cord injury. Occasionally, an associated tumor thrombus may embolize and may possibly cause sudden death.[19] The mortality rate for embolization with a variety of techniques has been reported to be ≤3.3% when embolization is used for palliation in inoperable cases.[20] However, the actual complication rate for preoperative embolization is probably lower.

It should be noted, however, that the use of embolization has never been demonstrated to provide benefit in a randomized controlled trial.[17,21] Subramanian and colleagues, in a retrospective review of 255 patients, actually found patients undergoing radical nephrectomy and inferior vena cava (IVC) thrombectomy who received preoperative angioembolization had a greater transfusion rate, longer operative time, more postoperative complications, longer intensive care unit stay, and increased perioperative mortality; no differences were found in intraoperative complications or length of hospitalization.[21] However, as noted, this was a retrospective study and, to date, no prospective study has been completed.

Vessel Dissection

Among the principles of radical nephrectomy, as originally described by Robson and colleagues,[2] are early control and ligation of the renal vasculature to prevent hematogenous tumor spread. Regardless of the incision used, the renal artery should be ligated first to prevent renal congestion. Careful dissection is necessary to confirm the identity of the renal artery. Depending on the approach, the celiac artery, superior mesenteric artery, contralateral renal artery, and lumber vessels may all be mistaken for the renal artery. If an injury occurs to one of these vessels, immediate recognition and primary repair will minimize subsequent complications. Consultation with a vascular surgeon, if available, is suggested. When approaching the renal artery, care should be taken to prevent avulsion of any branches listed earlier. Adrenal arterial branches are particularly prone to such injury. Although they are small, they may bleed profusely.

The renal artery may be clamped but left undivided if the anatomic features dictate it. Once the renal vein is ligated and divided, exposure to the renal artery may be improved. If the renal vein does not decrease in size after ligation of the renal artery, multiple renal arteries may be present.

The renal vein must be handled with care because a lumbar vein may drain posteriorly into it, especially on the left. The thinner walls of the vein make avulsion of these small veins a real possibility. The distal segment may retract

into the paraspinous muscles and render hemostasis difficult. Prevention of this complicating factor begins with recognition. Preoperative imaging may be helpful in some cases.[22] If lumbar veins are visualized, some incisional approaches with more limited visibility should be avoided. If avulsion of these veins occurs, compression of the bleeding site while completing removal of the kidney will improve exposure and thereby facilitate hemostasis. Figure-of-eight sutures in the paraspinous muscle to oversew the bleeding site are usually effective. A bolster of Surgicel (an oxidized cellulose hemostatic agent; Johnson & Johnson Wound Management, Somerville, NJ) placed under the figure-of-eight suture will assist in tamponade of the retracted vein.

Hematoma

Hematoma formation following radical nephrectomy may complicate the patient's postoperative course. In addition to the ability of the retroperitoneum to hold large amounts of fluid, the potential space left behind from bulky tumors allows significant bleeding without causing symptoms. The patient's hematocrit and blood pressure should be carefully followed, and one should realize that healthy individuals may lose up to 25% of their intravascular volume before significant symptoms occur. Even small hematomas may become infected and form abscesses. Verification of a dry surgical bed is an absolute necessity.

Drains are not routinely needed for nephrectomy. When significant intraoperative hypotension has occurred, some vessels may be in spasm, which may cause delayed postoperative bleeding. Placement of a closed drain for 24 to 48 hours postoperatively will permit early identification of bleeding.

INJURY TO NEARBY ORGANS

Spleen

Splenic injury is a well-known complication of intra-abdominal surgery, and left nephrectomy is the third leading cause of iatrogenic splenic injury.[9] Wide ranges of statistics are given (from 2% to 26%), but most modern series report splenic injury in approximately 1–5% of cases.[23,24]

Risk factors for splenic injury include prior abdominal surgical procedures, obesity, increasing age, large left kidney (i.e., polycystic kidney disease), and upper pole lesions.[25] Most case series show very different rates in donor nephrectomy–associated splenectomy and in splenectomy complicating radical left nephrectomy for neoplastic disease. Cooper and colleagues speculated that this discrepancy reflects the different goals of surgery.[25] Donor nephrectomies carry a risk of splenectomy of only 1–2%.[25,26] In addition, retroperitoneal approaches carry a much smaller risk of splenic injury.

Prevention of splenic injury begins with careful planning of the surgical approach and recognition of the importance of adequate exposure to the upper pole of the left kidney.[27] Splenic injuries occur in different ways. The most common cause is excessive traction on the splenic attachments that rips the splenic capsule. In addition, direct injury during dissection of large tumors may lacerate the splenic capsule, and retractors may damage the spleen if excessive force is placed on them or if countertraction is too great. In addition, direct injury during division of the diaphragm is a rare cause of injury from thoracoabdominal incisions.

Avoidance of splenic injury requires an understanding of the splenic attachments. The spleen is attached to all surrounding structures including the diaphragm, colon, stomach, and kidney (the lienophrenic, lienocolic, lienogastric, and lienorenal ligaments, respectively). The most superficial attachment, a lieno-omental band, was described by Lord and Gourevitch.[28] Early division of the inferior lienocolic and lienorenal attachments allows safe retraction of the spleen, although care should be taken to pad all retractors well and to avoid excessive pulling. Some investigators advocate coloepiploic mobilization or separation of the greater omentum off the colon from the midpoint of the transverse colon to the splenic flexure. Mejean and associates retrospectively demonstrated decreased rates of splenic complications ostensibly from increased splenic mobility as a result of early and more complete division of the colic attachments.[29] These investigators further suggested that the subcostal incision is superior to the midline incision for avoiding excessive traction on the splenic ligaments.[23]

Splenic injury is easily recognized by immediate bleeding from this highly vascular organ. Traditional treatment proceeded to immediate splenectomy. Increasing experience with splenorrhaphy from trauma surgery shows that significant numbers of spleens may be salvaged. Superficial lacerations may be treated with argon beam coagulation or hemostatic products such as Avitene (Davon, Cranston, RI) or Surgicel. Packing with laparotomy sponges to promote hemostasis followed by repeat examination is recommended. Deeper lacerations may require bolsters or splenic wrapping with mesh to tamponade the bleeding. Excessive intraoperative bleeding may be controlled by manual compression of the splenic vessels as they course near the tail of the pancreas until splenorrhaphy or splenectomy is completed.

Postoperative management of splenectomy includes vaccination for pneumococcal, *Haemophilus,* and meningococcal infections. Some investigators advocate preoperative vaccine administration to patients who are undergoing left nephrectomy and who have risk factors for splenectomy because the morbidity is minimal compared with the risk of postoperative vaccine administration.[25] Sepsis in splenectomized patients is much more serious than in immunocompetent persons, and the incidence is probably ≥10 times greater. Drains in splenectomized patients, if used, should be removed as quickly as possible to decrease the risk of overwhelming infection.[25]

Pancreas

Pancreatic injuries are rare compared with injuries of other nearby organs. Historical series in open kidney donor nephrectomies gave an incidence of <1%.[26] Pancreatic injuries may occur with right nephrectomy during performance of Kocher's maneuver to mobilize the second portion of the duodenum. However, most injuries occur secondary to the close proximity of the tail of the pancreas to the hilum of the left kidney. Retraction, avulsion of surrounding structures, and direct laceration may all injure the organ. Intraoperative bruising may also cause postoperative pancreatitis or asymptomatic elevation of amylase and lipase concentrations. Risk factors probably include prior operations, inflammation surrounding the kidney, larger lesions, or any other cause of difficult dissection.

Prevention of pancreatic injury includes development of the plane between Gerota's fascia and the visceral peritoneum during dissection of the superomedial pole of the left kidney. Identification, complete mobilization, and careful retraction of the pancreas will help to avoid any avulsion injuries.

Recognition of pancreatic lacerations requires immediate repair. It is important to inspect for injury to the pancreatic duct. If no injury is noted, simple repair of the pancreatic capsule with nonabsorbable suture and an omental bolster is all that is necessary. If the duct is involved, distal resection of the pancreas is probably preferable. General surgical consultation should be obtained if available. The distal pancreas is resected and the duct is closed. The capsule of the pancreas is then closed over the stump. In these cases, placement of a surgical drain is indicated.

Postoperative management of the patient who has undergone significant pancreatic manipulation includes monitoring of amylase and lipase levels, especially as the patient begins to eat. Any patients with significant injury to the pancreas require placement of a nasogastric tube. Parenteral alimentation should be considered early in the postoperative course. If clinical signs or symptoms of pancreatitis do not resolve, a CT scan should be performed. Fluid collections possibly representing a pancreatic leak, if found, require aspiration by interventional radiologic means. The fluid should be sent for measurement of amylase, lipase, pH, Gram stain, and culture. Infected liquid suggests the presence of necrotizing pancreatitis and requires emergency laparotomy for debridement and drainage. If the fluid is not infected, a percutaneous drain should be left and total bowel rest instituted. The addition of octreotide decreases pancreatic output and may be helpful in some cases. The starting dose is 50 μg subcutaneously three times daily, with titration up to 200 μg three times daily based on fistula output.[30]

Duodenum

Duodenal injuries most commonly occur during dissection anteromedial to the right kidney. The second part of the duodenum is most commonly involved. Far more uncommon is injury to the distal duodenum immediately adjacent to the ligament of Treitz. Such injuries occur on reflection of the left mesocolon medial to the inferior mesenteric vein where the mesocolon can be quite thin, or due to thermal injury or direct laceration.

Duodenal injuries are rather rare; in one series only a single injury to the duodenum occurred in 344 right nephrectomies.[23] Risk factors may include prior operations, inflammation surrounding the kidney, larger lesions, or any other cause of difficult dissection and adherence of the duodenum.

Prevention of duodenal injury includes careful dissection and the use of padded retractors. When necessary, Kocher's maneuver mobilizes the duodenum away from the operative field.

Careful inspection of the duodenum for lacerations and hematomas should be performed. Duodenal laceration should be closed with a two-layer technique and possibly reinforced with omentum or jejunum. If a duodenal hematoma is found, it should be opened and drained to prevent transient small bowel obstruction. The duodenum can then be repaired and covered with an omental bolster or jejunal tissue. If more extensive injury occurs, general surgical consultation should be considered. With standard preoperative prophylactic antibiotic coverage only for skin organisms, consideration should be given to adding gram-negative and anaerobic coverage, especially if no bowel preparation was used. Postoperatively, nasogastric suction should be maintained until intestinal peristalsis resumes.

Liver

Liver injury during nephrectomy in general is relatively rare. Many large case series list no liver lacerations. Causes of liver injury generally include forceful retraction during right nephrectomy. Preventive measures include adequate padding of retractors and division of the triangular and coronary ligaments if necessary to achieve adequate mobilization.

On recognition of a liver injury, or during intentional resection of liver extensions of the primary tumor, the liver laceration may be managed with Bovie or argon beam coagulation. For larger defects, Surgicel bolsters with horizontal mattress sutures of 2-0 silk or 1 chromic gut on a blunt-point needle may be more appropriate. If bleeding makes repair difficult, total obstruction of hepatic vascular inflow may be obtained by Pringle maneuver (Fig. 37.4). The hepatic artery and portal vein are isolated at the porta hepatis and are cross-clamped. Studies in liver donors indicated that significant ischemic injury does not take place with intermittent total occlusion from 10 minutes progressing to 30 minutes alternating with 5-minute reperfusion intervals.[31] If the extent of liver injury is judged to present a risk of postoperative bile leakage, drain placement is indicated.

If recognized and treated appropriately, iatrogenic liver injuries typically follow an uncomplicated course

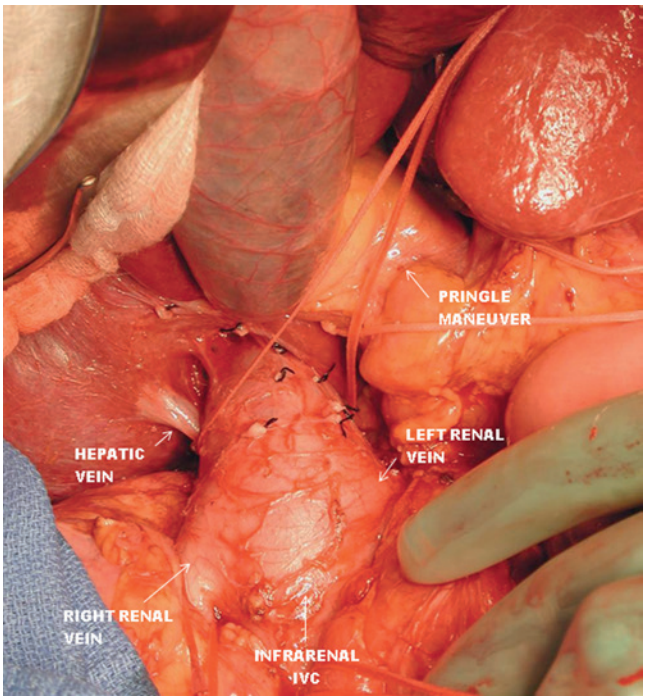


Figure 37.4 Photograph demonstrating technique for isolation of the porta hepatis for possible Pringle maneuver. In addition, umbilical tapes isolate the right renal vein and the inferior vena cava above and below the tumor.

postoperatively. If a significant bile leak develops, percutaneous drainage is indicated. Low-output fistulas typically close with conservative management, whereas high-output fistulas may require intervention with minimally invasive techniques.

Colon and Stomach

Injuries to the stomach, colon, and jejunum or ileum are very rare and are generally thermal injuries from accidental electrocautery arcs. Similar risk factors exist and probably include prior operations, inflammation surrounding the kidney, larger lesions, possibility of tumor extension into surrounding organs, or other causes of difficult dissection. Preventive measures include mechanical bowel preparation if the chance exists of tumor extension complicating resection or necessitating bowel resection. Closure of any hollow viscus is generally accomplished with a double-layer technique with possible omental bolstering. If unanticipated spillage of colonic contents occurs, extensive irrigation with sterile water, drain placement, and postoperative antibiotic prophylaxis for gram-negative and anaerobic organisms should be initiated.

Adrenal Glands

Radical nephrectomy as outlined by Robson and associates included adrenalectomy to maintain the integrity of Gerota's fascia.[2] Improvements in imaging have allowed improved preoperative assessment of tumor volume, extension, and adrenal involvement. In addition, significant stage migration resulting from increasing numbers of incidentally found tumors at early stages mandates reassessment of the practice of routine adrenalectomy. Studies of pathology specimens showed that the incidence of adrenal invasion is directly related to the stage of the primary lesion. Stage T1/2 lesions in general have a <2% chance of adrenal involvement if no adrenal abnormalities are seen on preoperative CT. Upper pole lesions, multifocal lesions, and radiologic stage T3/4 lesions have a much greater incidence (from 7.8% for T3 to 40% for T4).[32–35] In addition, up to one-third of patients with adrenal involvement show evidence of extensive nodal or metastatic disease.[36] However, most experts agree that adrenalectomy is indicated when there is either an abnormal radiographic appearance of the adrenal gland on preoperative imaging or concerning intraoperative findings.[37]

In light of the foregoing data, some surgeons perform adrenal-sparing radical nephrectomies in some patients to spare them from future adrenal insufficiency if metachronous contralateral disease develops that requires adrenal resection. In these patients, the chance for adrenal injury exists during renal mobilization. Usually, a well-defined plane separates the adrenal gland from the kidney. If this plane is not developed sufficiently, traction on the kidney may result in tears of the adrenal capsule, which may bleed profusely. Small injuries may be oversewn or treated with a vessel-sealing device. However, adrenal hemostasis using these methods is marginally successful and adrenalectomy is often the best solution. The vasculature of the adrenal gland, discussed earlier, is at particular risk of injury during nephrectomy, whether adrenalectomy is planned or not.

Diaphragm

Perforation of the diaphragm and parietal pleura with resulting pneumothorax is a possible complication of renal surgery regardless of the approach. The incidence probably rises with increasingly superior flank incision sites. Rates of iatrogenic pneumothorax through sub-12th rib flank incisions are negligible, whereas 11th interspace and 10th interspace incisions have a moderate risk. The overall risk of pneumothorax in modern series varies from 1% to 10%. In general, pneumothoraces requiring chest tube placement occur in approximately 1% of cases.[38–41]

Prevention involves careful attention to the anatomic features during dissection of the diaphragm off the costal attachments. For operations in which Gerota's fascia is opened, such as partial nephrectomy, this tissue can be used to buffer the upper aspect of the flank incision from the retractor. Many surgeons routinely obtain a postoperative chest radiograph to assess for pneumothorax requiring chest tube placement. Several studies examined the necessity for routine chest radiography postoperatively and concluded that it was unnecessary.[42,43] Although the incidence of pneumothorax from the variety of incisions discussed earlier is variable, this complication is usually recognized intraoperatively. The investigators found that only approximately 1% of patients undergoing nephrectomy had pneumothoraces of potential clinical significance that were missed intraoperatively. Many of these pneumothoraces resolved spontaneously with no negative consequences. The investigators concluded that routine chest radiography is unnecessary. Chest radiography should be obtained on the basis of intraoperative pleural injury or postoperative indications such as central line placement, symptoms, or physical examination findings.[42]

If a pleural injury is detected intraoperatively, it should be covered with a sponge to prevent entry of blood from the surgical field into the pleural cavity. At the end of the procedure, a 10 to 12Fr Robinson catheter can be passed through the pleurotomy to aspirate the air. A pursestring suture is placed around it. The distal end of the catheter is placed under water while the anesthetist hyperinflates the lung to 40 mm Hg. Attention should be paid to blood pressure because cardiac preload is decreased with lung hyperinflation. The catheter is then removed and the suture is tied to close the defect. If the pleurotomy is too large to close with this technique, chest tube placement is probably advisable. If no intrathoracic bleeding is noted, a smaller chest tube may be placed, or even a pigtail catheter can be inserted into the second intercostal space. Careful closure of the diaphragm with the sutures on the abdominal side of the repair facilitates pleural healing. Postoperatively, pneumothorax should be monitored with serial upright end-expiratory chest radiographs to verify resolution before the chest tube is removed.

Infection

Currently, infectious complication rates from nephrectomy excluding superficial wound infections are approximately 3–5%.[39] To minimize the risk of spreading infection, the urinary tract's normal sterile state must be verified preoperatively. Positive preoperative urine culture necessitates adequate antibiotic coverage for several days before the surgical procedure. Postoperative infections after any surgical procedure include wound infections, abscesses,

pneumonia, pyelonephritis, cholecystitis, and infections caused by antibiotic treatment such as *Clostridium difficile* colitis. Our discussion focuses on those infections that may be more specifically related to nephrectomy.

PNEUMONIA

Postoperative pneumonia is a common nosocomial infection to which patients undergoing nephrectomy may be especially prone. Radical nephrectomy for neoplastic disease is associated with a greater incidence of pneumonia compared with nephrectomy for benign conditions.[15] Some degree of atelectasis is nearly universal in patients undergoing general anesthesia, especially if the operation is performed with the patient in the flank position. The proximity of the incision site to the diaphragm and the division of accessory muscles of inspiration make deep breathing painful during the postoperative period. This situation perpetuates the stasis of fluid in the atelectatic lung segments, fluid that serves as an ideal culture medium for nosocomial pathogens. Major surgery may also suppress the immune system and thus increase susceptibility to infections.

Prevention of postoperative pneumonia includes preoperative evaluation of respiratory reserve and pulmonary status. Consultation with a pulmonologist is indicated if any doubt exists about the patient's status or if the patient has any history of obstructive, restrictive, or severe infectious pulmonary diseases. These risk factors should be addressed and minimized by adequate treatment preoperatively. Postoperatively, adequate pain control, incentive spirometry, and early ambulation are important for quickly decreasing atelectasis and the risk of pneumonia.

ABSCESS

Abscess formation is a rare complication of urologic surgery (1.7% in one series for renal cell carcinoma).[23] Risk factors are similar to those for wound infection, including preoperative urinary tract infection, entry into gastrointestinal organs, entry into kidney parenchyma or collecting system, and postoperative renal hemorrhage. In addition to avoidance of these risk factors, adequate irrigation, prophylactic antibiotics, and drain placement if indicated minimize the chance of abscess formation. In the presence of risk factors for infection, unexplained postoperative fever should prompt an abdominal CT search for an abscess. If an abscess is found, treatment involves percutaneous drainage by interventional radiologic means and empirical antibiotics. Antibiotic coverage is adjusted if necessary when culture and sensitivity results become available. With increasingly precise interventional radiology techniques, open debridement of abscesses is rarely necessary.

Special Populations

TUMOR THROMBUS

Renal cell carcinoma frequently involves vascular structures. Ten percent to 25% of tumors show thrombus.[44,45] Such vascular extension may manifest as lower extremity edema, varicocele, dilated superficial abdominal veins, proteinuria, pulmonary embolism, right atrial mass, or loss of function in the involved kidney. If a tumor thrombus is found, surgical preparation should include a magnetic resonance imaging (MRI) scan in addition to other preoperative imaging studies, to assess the proximal extent of the tumor thrombus (Fig. 37.5).[46–50] Preoperative MRI accurately measures the extent of tumor thrombus in approximately 98% of cases.[51] If an interval of ≥2 weeks exists between MRI and the surgical procedure, for level II and III thrombus, a follow-up study, such as ultrasound, transesophageal echocardiography, or repeat MRI, should be considered to ensure that significant thrombus propagation has not occurred. Invasive approaches, such as venacavography, are rarely indicated.



Figure 37.5 This 52-year-old man was found to have a tumor thrombus in each of his two right renal veins, each extending into the inferior vena cava separately. This MRI was obtained to confirm the proximal extent of tumor thrombus.

Fortunately, tumor thrombi do not necessarily indicate metastasis, and survival of patients after complete removal is better than in patients with primary tumor invasion into Gerota's fascia. Although some centers are describing minimally invasive techniques for management of lower level tumor thrombi, tumor thrombus remains one of the main indications for open surgical management.[52] In patients with level III or IV tumor thrombus, the importance of adequate preoperative assessment of the cardiopulmonary system should be emphasized in the presence of possible cardiopulmonary bypass.

An uncommon complication of tumor thrombus extension above the hepatic veins is Budd-Chiari syndrome or hepatic venous outflow obstruction. The classic acute presentation of Budd-Chiari syndrome consists of sudden-onset ascites, hepatomegaly, right upper quadrant pain, and elevated liver function test results. This syndrome is rarely seen in renal cell carcinoma–associated tumor thrombus formation, in which a more gradual onset of similar symptoms is typical.[53] Treatment involves an expeditious surgical

procedure to relieve hepatic vein obstruction and thereby spare liver parenchyma if possible. In spite of surgical intervention, severe symptoms usually indicate irreversible liver injury and the onset of hepatic failure. The largest series of patients with renal tumor thrombus–induced Budd-Chiari syndrome showed no survival for >6 weeks in seven patients with severe cases. The outcome of five patients with mild cases was probably similar to that in patients with equivalent renal disease without Budd-Chiari syndrome.[53] Surgeons should carefully consider patient selection for surgery in the presence of Budd-Chiari syndrome in light of probable poor outcomes.

Surgical technique for vena cava thrombectomy has undergone many changes. Because all investigators agree that the proximal level of tumor thrombus dictates the surgical approach, accurate assessment with preoperative imaging is important. At least six systems to categorize thrombi have been proposed.[54,55] Probably the most widely used is the Mayo Foundation (Rochester, MN) classification, which divides thrombi into four groups based on their relationship to the renal vein ostia, hepatic veins, and diaphragm.[56] Various surgical approaches have been advocated for every level.

Basic principles guiding the choice of surgical approach are as follows:

1. Adequate exposure of the primary lesion
2. Adequate exposure to the vena cava
3. Exposure of the contralateral renal vein
4. Ability to mobilize the liver
5. Ability to extend incision if necessary to include the chest
6. Complete control of vena cava above and below the thrombus to avoid pulmonary embolism
7. Avoidance of cardiopulmonary bypass if possible
8. Protection of natural venovenous shunt pathways.

The inferior vena cava above and below the thrombus, both renal veins, and the portal vein should be isolated with umbilical tape and Rummel tourniquets (see Fig. 37.5). Lumbar veins that will be draining into the opened area of the inferior vena cava are best ligated beforehand. The sequence of vascular control of the IVC prior to thrombectomy should be the IVC below thrombus, the contralateral renal vein and lumbar veins, and, finally, the IVC above the thrombus (demonstrated in Video 1). If an unrecognized lumbar vein is bleeding into the open vena cava to a significant extent, it can be occluded either posterior to the vena cava with a sponge stick or within the vena cava with a Kittner device. The Rummel tourniquets can be tightened to occlude the major veins. Alternatively, Satinsky and vascular clamps can be used. Although some vascular surgeons prefer not to use clamps on the vena cava, we have not encountered problems with this method.

Ligation of the short hepatic veins permits increased hepatic mobilization and isolation of an additional 4 cm of infrahepatic vena cava. This technique facilitates infrahepatic vena cava control as well as rotation of the liver to the left side of the inferior vena cava and thus gives excellent exposure to the right adrenal gland and retrohepatic inferior vena cava (Fig. 37.6).

When the tumor thrombus extends into the right atrium, opening the chest cavity is often necessary. This procedure

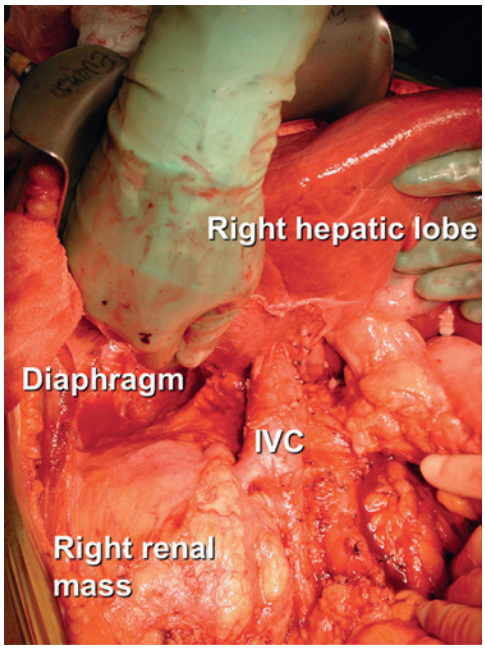


Figure 37.6 Photograph of liver rotated to the left to allow exposure of the retrohepatic vena cava. Note the ligated hepatic veins. IVC, inferior vena cava.

may be accomplished by midline sternotomy, thoracoabdominal incision, or xiphisternal extension of a chevron incision. A second small parasternal incision has also been described to access the thoracic cavity. The extent of tumor thrombus and whether or not it invades significant portions of the vena cava or right atrium dictate the operative time needed for complete excision. This time, in turn, dictates the need for venovenous bypass or hypothermia, cardiac arrest, and exsanguination.[54] Several groups have developed excision techniques for increasingly proximal levels of thrombi without cardiopulmonary bypass through transabdominal approaches.[57] Regardless of the approach, the complication most to be avoided is fragmentation of the thrombus leading to pulmonary embolism.

Verifying complete thrombus removal before reestablishing venous flow is critical. Various methods for removing remnant clot have been described, including manual "milking down" of the thrombus, placement of a Foley catheter past the thrombus followed by inflation and removal, and direct visual techniques employing flexible cystoscopes.[58]

Some complications of nephrectomy with thrombus removal are secondary to inadequate reconstruction of the inferior vena cava. Decreased cardiac preload may cause heart failure in some individuals with limited reserve. Decreased renal drainage of the contralateral kidney may cause acute renal insufficiency requiring dialysis. This condition may be reversible with the development of venous collateral vessels. It is always advisable to perform reconstruction of the inferior vena cava with graft material if inadequate vein remains following resection of adherent tumor thrombus. If the chest cavity is open, defatted pericardium may be used as autologous graft material (Fig. 37.7).

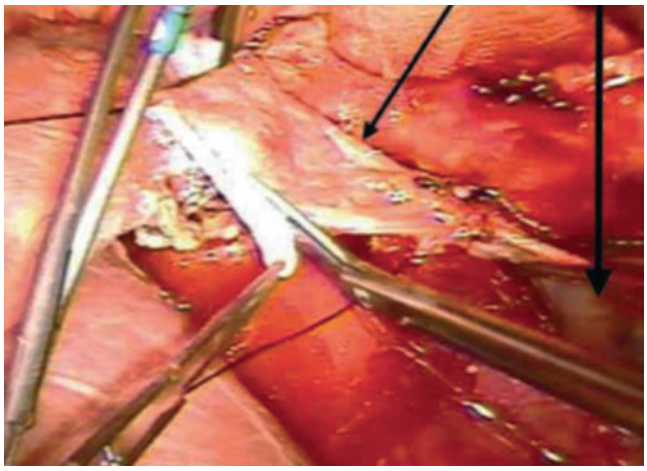


Figure 37.7 Reconstruction of the inferior vena cava with defatted pericardium. The thin arrow indicates the medial border of the graft sewn to the vena cava. The thick arrow indicates the vena cava inferior to graft.

Cardiopulmonary bypass may be associated with small increases in morbidity Most morbidity related to the bypass itself is from two different mechanisms. First, cardiopulmonary bypass results in a systemic inflammatory response through multiple biochemical mechanisms. These mechanisms are generally brought about by contact of the blood with the extracorporeal gaseous interface and biocompatible surfaces of the cardiopulmonary bypass machine. The inflammatory mediators (complement, cytokines) activate leukocytes, vascular endothelial cells, and platelets and generate a systemic response that damages organs.[59] Second, cardiopulmonary bypass generates multiple small emboli from lipoprotein aggregates, gaseous emboli, and other particulate matter. These affect end-organ capillary beds, particularly in the heart, brain, lungs, and kidneys. Healthy individuals with adequate reserve usually have no problems, but patients with significant comorbidities of any of these organs may be significantly affected.[59] Ongoing research is focused on overcoming these difficulties.

Other postoperative complications of cardiopulmonary bypass are usually manageable. Bleeding from heparinization and inadequate reversal with protamine may be extensive. Patients may also experience continuing temperature dysregulation following bypass. In addition to complications of cardiopulmonary bypass, hypothermic circulatory arrest leads to ischemic damage to body structures, some of which may be irreversible. Neural tissue is especially susceptible to such injury, and temporary neurologic dysfunction, stroke, and death may result. These complications are generally rare in radical nephrectomy.[60] Prevention includes shortening operative time to decrease the risk of ischemia. Despite these added risks, hypothermic circulatory arrest may decrease the risk of warm ischemia to the liver and contralateral kidney. Increased visualization and operative time may reduce the risk of tumor thrombus embolization.[60]

A recent large multicenter international analysis reported the use of cardiopulmonary bypass in level III–IV tumor thrombectomy cases did not significantly impact cancer specific survival or overall survival.[61]

CYTOREDUCTIVE NEPHRECTOMY

Two prospective studies from the Southwest Oncology Group and the European Organisation for Research and Treatment of Cancer demonstrated a modest survival advantage for cytoreductive nephrectomy before immunotherapy.[62,63] Morbidity from the renal neoplasm itself, such as pain and hematuria, may require palliative nephrectomy even in patients with extensive metastatic disease. However, in patients with lower performance status, it is advisable to attempt more conservative measures such as improved pain control and renal angioinfarction.

One article compared morbidity and mortality of cytoreductive nephrectomy in patients with tumor thrombus with radical nephrectomy in patients who did not have metastatic disease. Zisman and colleagues[29] found no increase in complications of surgery compared with patients undergoing similar radical nephrectomies without metastatic disease.

LOCALLY RECURRENT DISEASE

Clinical series have reported an incidence of isolated local disease recurrence in the absence of other metastatic disease of <2%.[64–66] Any T stage primary tumor may be affected. It is controversial whether local recurrence represents remnant disease from positive margins, residual lymph node disease, recurrence in residual adrenal gland, or a form of metastasis.[67,68] Positive margin status during open nephrectomy should be rare in the absence of grossly evident disease. Careful dissection with the avoidance of tumor spillage should minimize this possible risk factor. Obviously, patients with positive margin status and patients with gross tumor spillage in the incision require close follow-up because surgical extirpation is the only efficacious treatment available for renal cancer.

In patients with no evidence of metastatic disease in whom resection of local disease recurrence is complete, long-term survival may be achieved at a rate of up to 40%.[64,69] Some investigators have suggested adjuvant immunotherapy in these patients to enhance outcomes.[2] Longer recurrence-free intervals may correlate with improved survival after repeat resection.[36,44]

Complications of repeat resection may be significant. Wide resection of the possible neoplastic recurrence may require en bloc resection of adjacent organs and may thus increase the risk of complications, infection, and perioperative mortality. While older series showed several mortalities,[70,71] more recent series showed a complication rate of 13–45%.[64,68,72,73] Because of the significant complication rate and the small chance of a survival benefit in patients with local recurrence and metastatic disease, these patients should be considered carefully for repeat resection.[74] No efficacy was shown for any adjuvant or adjunctive therapies, including chemotherapy, immunotherapy, external beam radiation therapy, or intraoperative radiation therapy.[68] As systemic therapy for renal neoplasms develops, recommendations regarding proper treatment of metastatic disease will undoubtedly undergo significant change.

DONOR NEPHRECTOMY

The ethical issues surrounding living donor nephrectomy depend in part on the actual morbidity and mortality of the

operation. At this time, most living donor nephrectomies in the United States are performed with minimally invasive techniques. In some other countries, miniaturization of the incision is practiced. Because the operation carries no direct medical benefit to the patient, optimization of outcomes is imperative. Investigators have estimated that the perioperative mortality rate is approximately 0.03% and that rate of major complications of donor nephrectomy is approximately 1–4%.[5,75–77] These rates, much lower than in nephrectomy performed for renal cancer, reflect the elective nature of the procedure, the extensive preoperative workup, and the ability to abandon the operation or resect the contralateral kidney.

Postoperatively, contralateral renal hypertrophy maintains the glomerular filtration rate between two-thirds and three-fourths that of preoperative levels. Long-term sequelae of donor nephrectomy include increased blood pressure, especially systolic, although most patients have blood pressure remaining in the normal range or easily managed mild hypertension. Rates of hypertension in kidney donors mirror national rates, but this finding may reflect selection bias favoring healthy donors. In addition, proteinuria compared with preoperative values develops in 13–22% of patients.[5,78] To our knowledge, no studies have shown any clinically significant effects from these complications of donor nephrectomy.[78–80]

The surgical technique for open donor nephrectomy is similar to that for simple nephrectomy. Different centers use a variety of incisions for the approach. Extraperitoneal approaches may minimize the risk of subsequent adhesions and possible small bowel obstruction requiring reoperation. Rates of small bowel obstruction were ≤2% in older series.[26] However, meticulous dissection of the renal pedicle with sparing of all renal vessels may be easier through an anterior transperitoneal incision, particularly if any aberrant vessels exist. Care must be taken when dissecting the ureter to avoid damaging the collateral vessels from the renal hilum to the proximal ureter. These vessels maintain blood supply in the transplanted organ, and damage to them may cause ureteral necrosis. Complete mobilization of the kidney is performed before the renal vessels are clamped, to minimize warm ischemia time. In the transplanted kidney, application of papaverine may be indicated to avoid possible renal artery spasm.

ELDERLY PATIENTS

Definitions of *elderly* have been changing as the population ages. Case series have moved from 60–65 years as age cutoffs to 70–75 years. Historically, elderly patients were thought to benefit very little from surgical extirpation of neoplasms because the morbidity and mortality associated with surgery were thought to exceed the benefit possible over the remaining life span. These concepts have changed significantly for many neoplasms including renal cancer. Studies have shown no significantly higher rates of morbidity and mortality for nephrectomy in elderly patients.[81] Indeed, most of the increased problems are probably the result of the greater number and incidence of comorbidities commonly associated with increasing age. These comorbidities can usually be managed preoperatively to optimize outcomes.[74,82]

Perioperative strategies to decrease complication rates include minimizing of operative time, earlier consideration of blood transfusions, and possible gastric tube placement to decrease pneumonia rates. Extraperitoneal approaches may decrease ileus and allow an earlier return to a normal diet, a factor that may be more important in elderly patients. Postoperative intensive care for 24–48 hours may allow earlier recognition of possible complications.

TRANSITIONAL CELL CARCINOMA

The current treatment standard for most cases of upper urinary tract transitional cell carcinoma is nephroureterectomy with a cuff of bladder. Low-grade, low-stage lesions may be managed more conservatively.[33] Increasing numbers of nephroureterectomies are performed laparoscopically in some centers. However, open nephroureterectomy still offers unparalleled exposure for difficult cases. It may be performed through many different incisions. Single incisions include midline or a combination of midline and subcostal. Alternatively, two incisions may be used such as a flank or subcostal combined incision with a Gibson or lower midline incision for distal ureteral dissection. In some cases, the distal ureter may be resected endoscopically or laparoscopically. Ideally, en bloc resection of the whole specimen is accomplished, although some institutions divide the ureter to make subsequent resection easier. Surgical dissection of the kidney is identical to that performed in radical nephrectomy. The adrenal gland may be spared in most cases. The cuff of bladder should be resected because this technique decreased the disease recurrence rate in one study.[22]

Complications of nephroureterectomy are similar to those of radical nephrectomy. Other complications associated with cystotomies such as urinoma or fistula formation are rare. In addition, the contralateral ureteral orifice may be damaged by the dissection of bladder cuff. This complication may result in anuria secondary to obstruction of the remaining ureter at the ureteral orifice. Gentle dissection prevents this complication. Management includes retrograde stent placement if possible or nephrostomy if stent placement fails.

References

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Chapter 37 Questions

1. During flank approach for nephrectomy, what step predisposes for flank sag/laxity?
   a. Resection of the 11th rib
   b. Incision in the 10th interspace
   c. Injury to the neurovascular bundle
   d. Too much flexion in the bed during positioning
   e. None of the above

2. Benefits of preoperative embolization include which of the following?
   a. Allows for earlier ligation of the renal vein
   b. Causes regression of tumor thrombus
   c. Easier dissection of the kidney due to formation of edematous plane
   d. All of the above
   e. None of the above, as no studies have demonstrated clear benefit

3. A 68-year-old man with a 15-cm right renal mass and associated level III tumor thrombus undergoes an open radical nephrectomy and tumor thrombectomy via a thoracoabdominal approach. There are no significant complications during the procedure, and while cardiopulmonary bypass is not required, operative time approaches 6 hours. Postoperatively, the patient is observed in the intensive care unit. A few hours postoperatively, the nurse calls noting slightly decreased urine output (~20–30 mL/hr); the patient also complains of left flank pain. On evaluation, he is hemodynamically stable, has some slight bruising of the left flank, and has tea-colored urine. What lab tests can be ordered to assist in diagnosis?
   a. Serum creatinine
   b. Urinalysis and urine microscopy
   c. Serum creatinine kinase levels
   d. Serum amylase and lipase
   e. b and c

4. In the above patient, what is the treatment of choice?
   a. IV hydration with urine output goal ~300 mL/hr
   b. Diuresis with loop diuretic
   c. Acidify the urine
   d. Immediate hemodialysis
   e. None of the above

5. During mobilization of the inferior vena cava in preparation for cavotomy for tumor thrombectomy, lumbar veins must be identified and controlled. If lumbar veins are to be ligated, it is more important to secure which side of the vein?
   a. The inferior vena cava (IVC) side since IVC bleeding will be difficulty to identify and control
   b. The distal aspect since these veins retract into the paraspinous muscle
   c. Both sides ideally, but if one side was preferred, then the inferior vena cava (IVC) side only since IVC bleeding will be difficulty to identify and control
   d. Both sides ideally, but if one side was preferred, then the distal aspect since these veins retract into the paraspinous muscle
   e. None of the above

6. The most common mechanism of splenic injury during open radical nephrectomy is which of the following?
   a. Direct injury during sharp dissection of the left kidney superior pole
   b. Direct injury to the splenic vessels
   c. Traction injury during retraction of the abdominal wall
   d. Direct injury to a previously unrecognized splenule
   e. None of the above

7. Though rare, if pancreatic injury is suspected and identified intraoperatively, which of the following steps should be taken?
   a. General surgery consultation
   b. Evaluation for pancreatic ductal injury
   c. Intraoperative serum amylase/lipase levels
   d. Abort procedure immediately
   e. a and b

8. The best imaging modality to assess for pneumothorax following open radical nephrectomy is:
   a. End-inspiratory lateral chest x-ray
   b. End-expiratory lateral chest x-ray
   c. End-inspiratory upright chest x-ray
   d. End-expiratory upright chest x-ray
   e. CT chest

9. If significant bleeding from the liver is encountered, hemostasis may be achieved through the Pringle maneuver. Which of the following structures is compressed during this maneuver?
   a. Hepatoduodenal ligament
   b. Hepatic artery proper
   c. Portal vein
   d. Common bile duct
   e. All of the above

10. Common symptoms of postembolization syndrome include which of the following?
    a. Nausea/emesis
    b. Flank pain
    c. Fevers/chills
    d. Epigastric pain
    e. a, b, and c

Case Studies

CASE 1

A 60-year-old man presents to your office for evaluation. He has been on hemodialysis for 5 years due to chronic kidney disease (stage V) initially thought to be due to hypertension and diabetes. However, during a recent ER visit for recurrent abdominal pain, he had a noncontrast CT scan completed (Case Fig. 37.1). He continues to have abdominal pain, early satiety, and decreased appetite.

1. What is the diagnosis based on CT imaging and clinical history?
   a. Bilateral renal masses concerning for renal cell carcinoma
   b. Bilateral multicystic dysplastic kidneys
   c. Bilateral ureteropelvic junction obstruction
   d. Adult polycystic kidney disease (APCKD)
   e. Bilateral parapelvic cysts

2. Based on the above diagnosis, you offer to proceed with bilateral nephrectomy for symptom management. What is the best approach?
   a. Thoracoabdominal incision
   b. Bilateral subcostal incisions
   c. Midline abdominal incision
   d. Bilateral lumbodorsal incisions
   e. Chevron incision



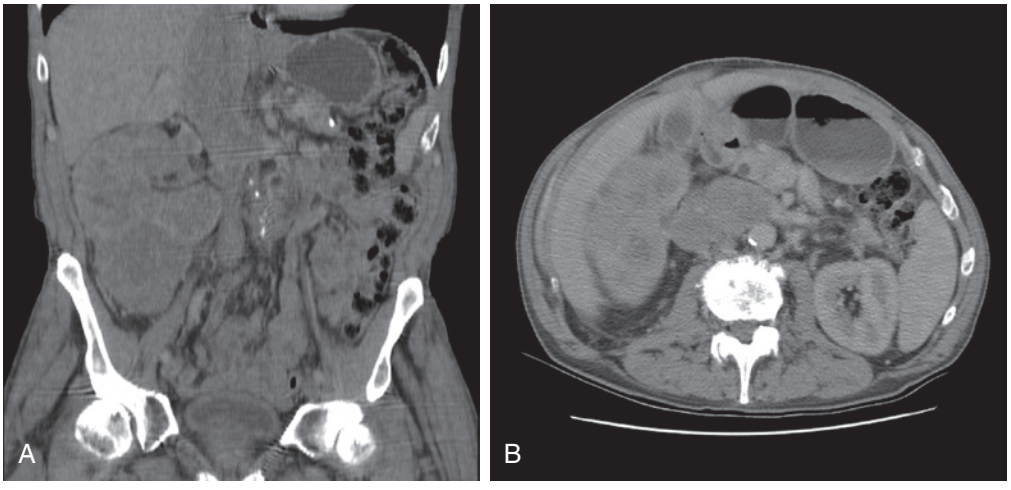
Case Figure 37.1

3. During mobilization of the left polycystic kidney, you notice significant bleeding from the left upper quadrant. Closer examination reveals traction injury to the spleen, limited to a superficial laceration. What is the next acceptable step in management of this superficial laceration?
   a. Suture the laceration with a 3-0 absorbable suture
   b. Immediate splenectomy
   c. Argon bean coagulation
   d. Placement of hemostatic product (Avitene, Surgicel) on the site
   e. c, d, and packing, with serial examinations throughout the case

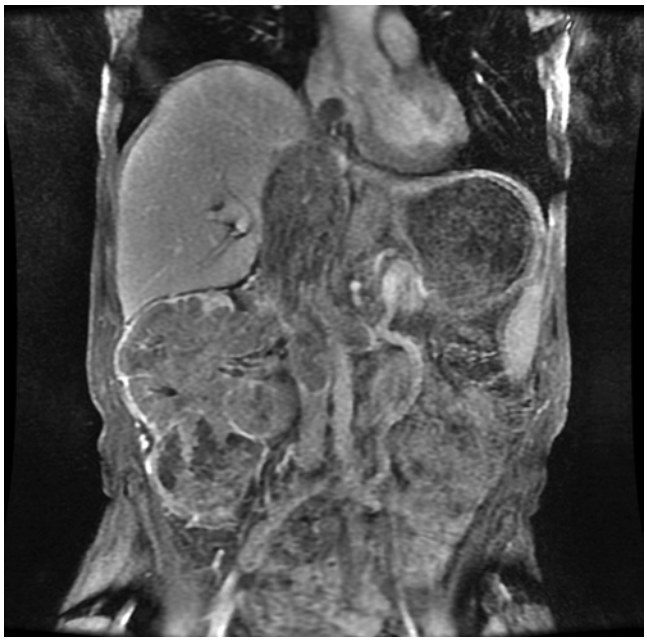
4. Patient does well postoperatively initially. However, he has slow return of bowel function and is managed conservatively for an ileus. On postoperative day six, he begins to develop fevers, subjective chills, worsening nausea, and increasing abdominal distention. CT abdomen/pelvis with contrast (coordinated with hemodialysis) is obtained – a 5-cm × 3-cm abscess of the left renal fossa is identified. What is the next step in management?
   a. Continue conservative management, this will resolve spontaneously
   b. Open exploration and drainage
   c. Consult interventional radiology for drain placement
   d. Blood cultures, broad-spectrum antibiotics
   e. c and d

CASE 2

A 55-year-old man, otherwise healthy, was seen by his primary care physician for a single episode of painless gross hematuria. She orders a tri-phasic CT and refers him to see you. Cystoscopy in the clinic is normal – no masses, stones, or other pathology identified. CT scan is still pending, so you tell the patient you will call him with results once it is completed. One week later, CT scan is completed and images are below (Case Fig. 37.2).



Case Figure 37.2



Case Figure 37.3

1. What is your next step?
   a. Bring patient back for discussion of imaging results
   b. Obtain chest imaging (chest x-ray)
   c. Obtain labwork (complete blood count, serum chemistries, liver function panel, INR/APTT)
   d. All of the above
   e. None of the above, let the primary care physician manage the patient

2. After seeing the above results (chest x-ray without evidence of disease, labwork otherwise normal), you meet with the patient and discuss plans to proceed with nephrectomy and IVC thrombectomy. You schedule him for surgery in 3 weeks. You want to reassess the thrombus prior to surgery–what is the best imaging modality to do so?
   a. Repeat CT abdomen with IV contrast
   b. Color Doppler ultrasound of the IVC
   c. Venacavography with interventional radiology
   d. MRI abdomen with contrast
   e. Transthoracic Echocardiogram

3. The MRI is completed a few days prior to the planned operation. Images are below (Case Fig. 37.3). You pre-admit the patient for angioembolization the day prior to surgery. On the day of surgery, what imaging modality is important to have available if there is concern for extent of the thrombus to the atrium?
   a. Intraoperative Doppler ultrasound
   b. C-arm and fluoroscopy
   c. Cardiac anesthesia and transesophageal echocardiogram (TEE)
   d. Portable CT scanner
   e. MRI scanner

4. You make a chevron incision for optimal exposure to the thrombus and hilum. The right colon is mobilized. In order to best access the suprahepatic IVC, what maneuver can be done?
   a. Pringle maneuver
   b. Hepatic mobilization and flip the right lobe into the left upper quadrant
   c. TEE
   d. Ligation of short hepatic veins to acquire more distance up the IVC
   e. a and c

5. Following removal of the kidney and tumor thrombus, you begin closure of the IVC. At the level of the renal ostium, the IVC appears to be significantly narrowed >50% when reapproximated. What is the next step in management?
   a. Close the IVC as it is–collaterals will develop over time without long-term consequences
   b. Utilize a graft to reconstruct the IVC to prevent narrowing
   c. Place a vascular stent prior to closure of the IVC to prevent thrombosis
   d. Ligate the IVC above and below the narrowed segment
   e. Utilize a portion of the renal vein to reconstruct the IVC

Answers

1. **c.** Up to 23% of patients have a flank sag postoperatively as a result of injury to intercostal nerves that causes laxity of flank muscles at that level.
2. **e.** While surgeons have completed angioembolization prior to nephrectomy based on anecdotal evidence, there have been no studies that have demonstrated clear benefit to pre-operative angioembolization.
3. **e.** This patient is demonstrating classic manifestations of rhabdomyolysis. After a long operation (6 hours) in a compromising position, tea-colored urine, acute kidney injury (decreased urine output), and bruising should all increase threshold for suspicion. Good diagnostic tests include urinalysis and urine microscopy (microscopic hematuria but without red blood cells in urine microscopy) and serum creatinine kinase levels (elevated).
4. **a.** The treatment of choice for patients with rhabdomyolysis is intravenous hydration with urine output goal ~300 mL/hr.
5. **d.** While it is always important to secure both sides of a lumbar vein, if only one side can be secured, then the distal aspect is preferred, as since these veins retract into the paraspinous muscle after ligation, which makes hemostatic control difficult.
6. **c.** The most common cause of splenic injury is excessive traction on the splenic attachments that rips the splenic capsule.
7. **e.** Recognition of pancreatic lacerations requires immediate repair. It is important to inspect for injury to the pancreatic duct, as duct involvement may indicate need for distal resectionof the pancreas. General surgical consultation should be obtained if available, as pancreatic leaks can be significant complications postoperatively. The capsule of the pancreas is then closed over the stump. In these cases, placement of a surgical drain is indicated.

8. **d.** The best instructions to provide for the x-ray technician to evaluate for pneumothorax postoperatively is to obtain am end-expiratory upright chest x-ray.
9. **e.** The Pringle maneuver allows for total obstruction of hepatic vascular inflow. The maneuver involves compression of the all the listed structures as one packet.
10. **e.** A common complication of embolization includes the embolization syndrome, which consists of nausea, vomiting, fever, and flank pain. Nephrectomy should be carried out ≤48 hours after embolization to minimize these symptoms.

CASE 1

1. **d.** The radiographic images are most consistent with adult polycystic kidney disease (APKD). Specifically, the numerous cortical cysts throughout both kidneys make this the most likely diagnosis.
2. **c.** A midline allows easy access to the renal pedicle and major vessels. However, in this specific situation, a bilateral nephrectomy for APKD, a midline approach is also important because it allows extension of the incision in order to access the low abdomen and pelvis in patients with large polycystic kidneys.
3. **e.** Superficial lacerations of the spleen can be managed conservatively. Argon bean coagulation and placement of hemostatic product (Avitene, Surgicel) on the site are recommended. Re-assessment throughout the case can ensure resolution of the bleeding.
4. **e.** As is the case for most postoperative abscesses, the management of choice is drainage (typically with the assistance of Interventional Radiology) as well as systemic therapy with antibiotics if fevers are present. Blood cultures are important to help tailor initial broad-spectrum antibiotic choices.

CASE 2

1. **d.** The CT scan work-up has revealed a large right renal mass with a large tumor thrombus. This patient will need urgent evaluation and be scheduled for surgery. As such, work-up for surgery can be obtained prior to the patient returning (pre-operative labwork), as well as additional staging studies (chest x-ray).
2. **d.** An MRI with contrast is the recommended study of choice for a patient with a tumor thrombus, as it accurately measures the extent of tumor thrombus in approximately 98% of cases. It is important for surgical planning.
3. **c.** Cardiac anesthesia and transesophageal echocardiogram (TEE) should be utilized for patients with Level IV thrombus to monitor thrombus intra-operatively and to provide information regarding the extent of the thrombus.
4. **b.** Access to the suprahepatic IVC can be obtained by mobilizing the liver and flipping the right lobe into the left upper quadrant. Specifically, ligation of the short hepatic veins permits increased hepatic mobilization, which allows rotation of the liver to the left side of the inferior vena cava and thus gives excellent exposure to the right adrenal gland and retrohepatic inferior vena cava.
5. **b.** Inadequate reconstruction of the inferior vena cava may lead to decreased cardiac preload and heart failure, decreased renal drainage of the contralateral kidney and acute renal insufficiency requiring dialysis, or formation of thrombi. It is always advisable to perform reconstruction of the inferior vena cava with graft material if inadequate vein remains following resection of adherent tumor thrombus. If the chest cavity is open, defatted pericardium may be used as autologous graft material.

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38 Complications of Open Partial Nephrectomy

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CHAPTER OUTLINE

Preoperative Considerations
Operative Planning
General Complications
Open Partial Nephrectomy: Incidence
Specific Complications
Positive Margin
Bleeding
Infarct
Urine Leak
Renal Function
Reoperation
Conclusions
Chapter 38 Questions and Answers

KEY POINTS

1. Knowledge of renal arterial anatomy is essential for performing partial nephrectomy.
2. Complication rates with both open and laparoscopic partial nephrectomy vary with operator experience, but both can be acceptable with careful attention to detail.
3. The risk of bleeding and urine leak should be balanced against the risk of renal dysfunction from prolonged arterial clamping.
4. Renal incision should be planned by ultrasound study according to arterial anatomy and should be started away from the hilum to minimize the risk of infarct.
5. Identification and direct suture ligature of retracted blood vessels within the line of incision avoid retracted sutures deep in the incision bed.
6. At the time of urine leak, the drain should be positioned to remove any extrarenal urine collections completely. A stent is rarely required unless ureteral obstruction is present.

Since first reports in 1869–1870 by Simon[1] and in 1887 by Czerny,[2] partial nephrectomy has been used to manage many different urologic diseases. The major application of partial nephrectomy since the early 1990s has been as an alternative to radical nephrectomy in the treatment of small renal tumors.[3–22] Several organizations now endorse partial nephrectomy as the standard treatment of small renal masses (cT1a, <4 cm) in those patients whose tumor is amenable to this approach.[23,24] This technique has proven to be oncologically safe for early tumors confined to the kidney. More recent efforts have been made to duplicate open partial nephrectomy techniques in minimally invasive tumor resection and thereby shorten recovery time and reduce postoperative morbidity. The significant downward stage migration of renal tumors resulting from increase in the incidental diagnosis has prompted investigators to expand indications and increase the use of partial nephrectomy.[25–27] Despite this change, the use of the partial nephrectomy remains low nationally, even for small renal tumors, which is likely a reflection of the perception of increased morbidity relative to radical nephrectomy.

Preoperative Considerations

The absolute indications for partial nephrectomy include tumor in a solitary renal moiety, bilateral renal tumors, or preexisting azotemia that would preclude the ability to perform nephrectomy without requiring that the patient undergo dialysis. Despite these indications, in selected patients of this type, nephrectomy followed by dialysis may be indicated for maximal oncologic efficacy. Relative indications include medical illnesses predisposing to renal disease, preexisting medical renal disease, renal stones, recurrent renal infection, mild azotemia, and multifocal tumors associated with a genetic syndrome. *Elective partial nephrectomy* is defined as that in which the patient has none of the foregoing risk factors, normal renal function, and a radiologically normal contralateral renal moiety. Studies have suggested a greater overall reduction in glomerular filtration rate (GFR) in patients undergoing radical nephrectomy as compared with partial nephrectomy (discussed later).[28] Because this finding may correlate with a higher likelihood of morbidity and mortality not related to oncologic factors,

the impetus for consideration of elective partial nephrectomy may be greater in the future.

In considering patients for partial nephrectomy, host factors to be considered include overall health and the ability to tolerate surgery, the presence of comorbidities predisposing to renal disease, bleeding diathesis or a need for anticoagulation, and baseline renal function. Although the need for perioperative anticoagulation does not preclude partial nephrectomy, it certainly does increase the risk of postoperative bleeding, and as such it may be a reason for considering nephrectomy in an otherwise fragile patient. Renal anatomic variants including duplication, anomalous location, and anomalous vasculature are important to be aware of in operative planning, but they do not preclude partial nephrectomy. Previous renal surgery for any indication must be evaluated carefully to ensure that partial nephrectomy will be feasible. Finally, body habitus may influence the operative approach and the decision for surgical intervention.

Retrospective studies demonstrated that patients undergoing partial nephrectomy have better long-term renal function than do patients undergoing radical nephrectomy.[2–31] Investigators have previously demonstrated that the likelihood of having a GFR >45 mL/minute or >60 mL/minute was greater among patients having a partial nephrectomy.[28] The inherent implication of these findings is that individuals undergoing partial nephrectomy may indirectly reduce their risk of nononcologic morbidity and mortality as a result of preserved renal function. A significant positive correlation exists between reduced GFR and cardiovascular mortality or other medical illnesses. Some investigators have suggested that the risk of cardiovascular or nononcologic mortality is greater among patients undergoing radical nephrectomy as compared with partial nephrectomy.[18,19,32] Whether this finding is ultimately related to selection bias remains to be determined in prospective evaluation. Nonetheless, the findings are provocative in suggesting that elective partial nephrectomy should be considered in most patients in whom the procedure is technically feasible, and broadening of the indications may be of value.

Consideration of the tumor is essential in selecting candidates for partial nephrectomy and in planning the surgical procedure. Tumor size and location should be considered within the framework of the surgeon's technical experience and comfort level when deciding whether partial nephrectomy is appropriate. In these tumors, an ample margin can be obtained with limited concern of damaging the remaining renal blood supply. Historically, elective partial nephrectomy was considered appropriate for exophytic tumors <4 cm. In retrospective evaluation of early series, central tumors and larger tumors had worse oncologic outcomes. Admittedly, the majority of patients in those categories may not have had elective indications for partial nephrectomy. As surgeons have become comfortable with the technique, indications for elective partial nephrectomy have been expanded to include central tumors, and those in the T1b (4–7 cm) category. Thus far, no apparent decline in cancer control has been reported among those series.[4]

Operative Planning

Operative planning of partial nephrectomy requires rigorous understanding of arterial anatomy and the relationship of blood supply and collecting system (Fig. 38.1). This knowledge allows planning of the necessity for renal ischemia, the line of resection for margin control, and the likelihood of necessary venous and collecting system repair. Several groups demonstrated the utility of preoperative three-dimensional image reconstruction using computed tomography (CT) or magnetic resonance imaging (MRI).[33] These modalities are extremely useful in identifying multifocality, anomalous vasculature, and venous tumor thrombus in segmental renal veins.

In recent years, the anatomic considerations for planning partial nephrectomy have been objectified through a number of spatial scoring systems that relate the tumor position to intrarenal structures. Most commonly employed is the nephrometry score,[34a] detailed in Chapter 34, which correlates with the risk of complications at time of partial nephrectomy. These scores can be quite useful both for selecting candidates for partial nephrectom, and for determining the optimal approach.

Planning of the incision is important. Partial nephrectomy can be performed through a variety of incisions (Figs. 38.2 A–C, and 38.3A and B) including a traditional flank, subcostal (intraperitoneal), thoracoabdominal, or the more recently described "mini-flank" (subcostal extraperitoneal).[34b] We prefer to perform open partial nephrectomy through an extraperitoneal approach, using a supracostal 11th rib incision. The advantages of such an approach include the ability to tamponade postoperative bleeding and contain urine leaks in the retroperitoneum, to reduce postoperative ileus, and to allow proper exposure for elongation of the renal hilum and "stretch" of the kidney. Disadvantages include increased pain limiting postoperative inspiratory effort, risk of pleural injury, and flank denervation bulge, which often arises from stretch of the intercostal nerve during rib distraction. The subcostal approach is feasible, but we have found it difficult to bring the kidney up to the level of the skin as we can easily do with hilar mobilization through a flank incision. The "mini-flank" incision may represent a compromise between these two approaches, by taking advantage of the benefits of each.

An additional preoperative consideration in contemporary practice is whether to perform the procedure by laparoscopic, robotic-assisted laparoscopic, or open technique. This decision is, in large part, a decision made on the basis of surgeon preference and experience, as it has been shown that the majority of tumors can be safely treated by any of the approaches. A number of considerations, detailed in Chapter 34, may come into play. In general, for most surgeons, open techniques are ideal in cases of centrally located tumors, complex tumor relationship with intrarenal structures, significant multifocality, large tumors, or solitary kidney. For surgeons not facile with minimally invasive techniques, open techniques can obviously be safely employed in any surgical setting. One should consider the morbidity specifically associated with the incision in selecting candidates.

A good benchmark is for the surgeon to determine, within his or her own skill set, an estimated ischemia time for renal reconstruction based on tumor size and position. Although the optimal time for tolerable ischemia is not clearly defined, we use a benchmark of 30 minutes by estimate. If it appears that >30 minutes would clearly be required,

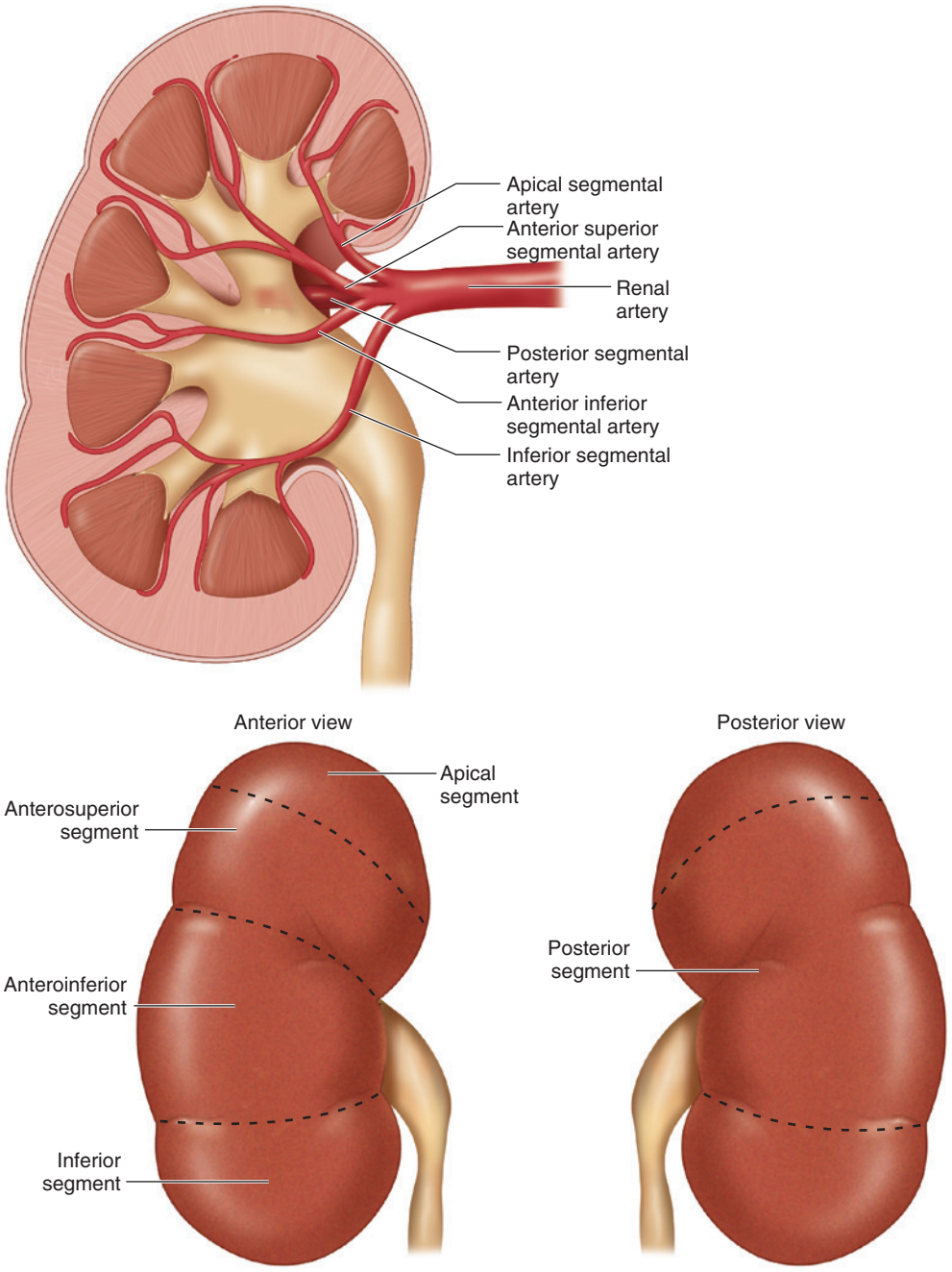


Figure 38.1 The arterial blood supply of the kidney is generally reproducible with five major segmental branches. On occasion, when a tumor is localized to a single arterial segment, selective segmental arterial occlusion may be feasible, thereby reducing the risk of renal ischemia. In resecting, the line of resection should not cross the direction of segmental flow, to avoid peripheral infarct. Similarly, on reconstruction, knowledge of the direction of blood supply relative to the defect is essential.

we would consider open partial nephrectomy. When using a transperitoneal laparoscopic approach, the most difficult tumors for exposure and resection are those located in the medial posterior segment. In these cases, a retroperitoneal laparoscopic approach can be considered if the surgeon is facile with the technique, but an open approach is a reasonable consideration otherwise. Increased morbidity for partial nephrectomy in a solitary kidney has been reported for laparoscopic as compared with open partial nephrectomy even in centers of excellence, a finding suggesting that these procedures are best performed by open partial nephrectomy in most cases.[35]

Given the more rapid general convalescence with laparoscopic partial nephrectomy techniques, in our center we have preferred this technique, in recent years, for most patients and reserve open partial nephrectomy only for those patients with significant multifocality or very centrally located tumor. We have found reoperative surgery, following previous partial nephrectomy, to be easier with a laparoscopic approach.

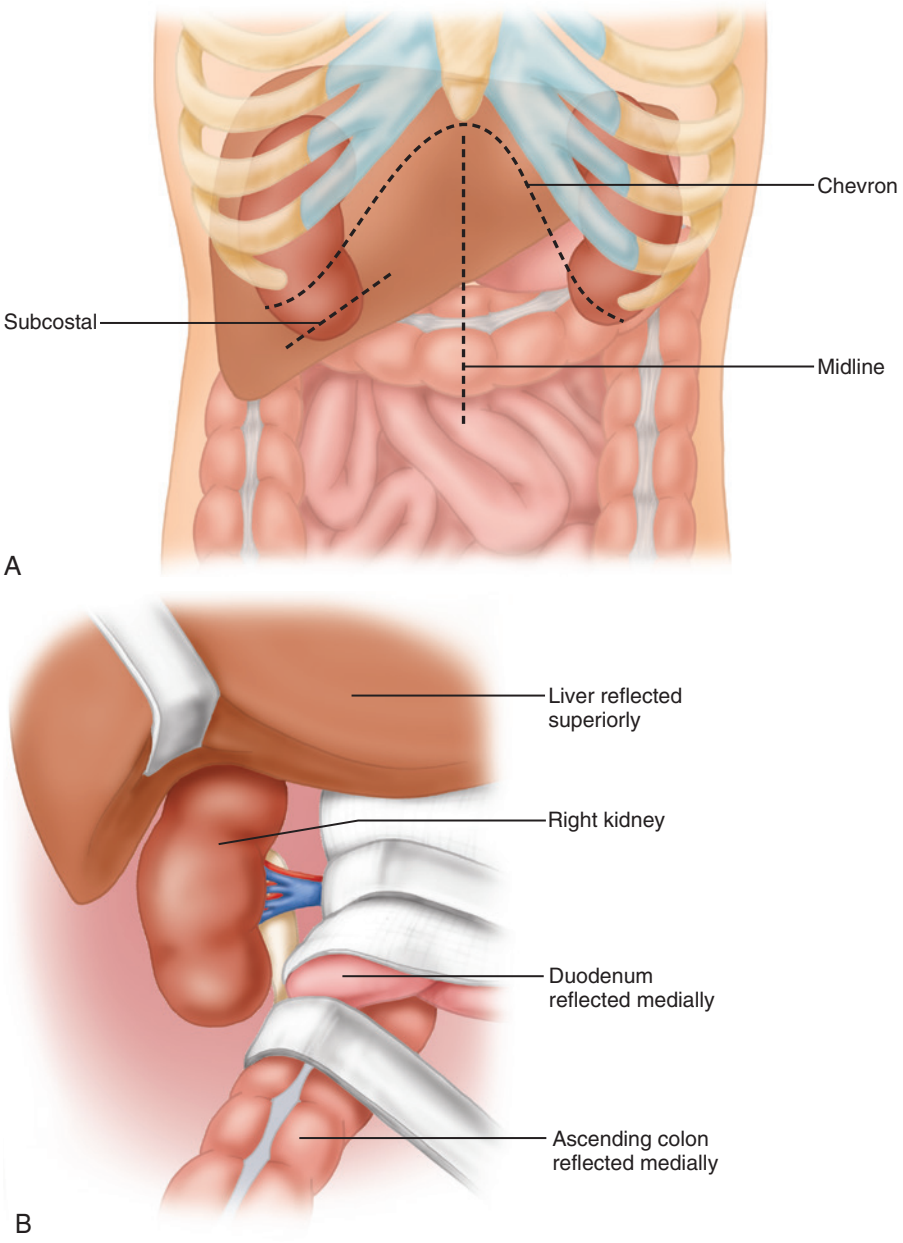


Figure 38.2 A number of options exist for anterior incisional approaches to the kidney (A), including unilateral or bilateral (chevron) subcostal or midline incisions. Transperitoneal, anterior exposure of the right kidney (B) requires reflection of the right colon, duodenum, and triangular ligament of the right hepatic lobe. Medial exposure should be carried out widely to the level of the inferior vena cava.

General Complications

The general complications related to the renal surgery, incision, and medical comorbidity are discussed elsewhere in this book. This chapter focuses attention on complications specifically related to partial nephrectomy. The main technical complications of partial nephrectomy include bleeding, urine leak, renal dysfunction, vascular fistula or malformation, positive margin, renal infarct, and, on rare occasions, renal loss.

The learning curve of partial nephrectomy remains a major challenge for the urologic community, but in more recent series morbidity is improving. In fact, some series comparing morbidity, length of stay, and cost differential associated with partial and radical nephrectomy reported no significant differences and concluded that the nephron-sparing approach can offer the benefit of maximal parenchymal preservation while adding little additional morbidity.[5,8,15,36,37] In a study of 49,983 individuals who underwent open radical nephrectomy (35,712), laparoscopic radical nephrectomy (5327), or open partial nephrectomy (8944) for RCC at 2037 hospitals from the Nationwide Inpatient Sample 2001–2008, only modest differences were observed in the proportion of patients with complications (27.0%, 22.6%, and 24.0%, respectively).[38]

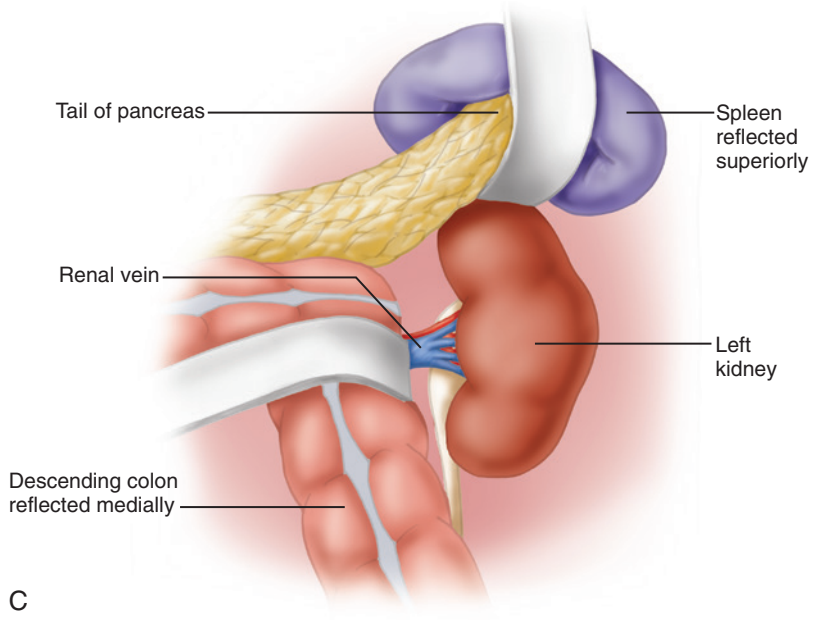


Figure 38.2, cont'd Left renal exposure (C) requires reflection of the left colon, pancreatic tail, and spleen. On occasion, incision of the splenocolic ligament is required. Medial exposure is generally carried out to the para-aortic space, but exposure of the aorta is generally not required, given the length of the left renal hilum. (From O'Malley RL, Godoy G, Taneja SS. Radical nephrectomy for localized renal cell carcinoma. In: Renal Cell Carcinoma. Campbell SC, Rini BI, eds. Shelton, CT; BC Decker; 2009.)

Becker et al. evaluated 2277 patients aged >65 years with T1 renal cell carcinoma who underwent laparoscopic radical nephrectomy, open partial nephrectomy, or laparoscopic partial nephrectomy, using the Surveillance, Epidemiology, and End Results Medicare linked database (1992–2005) and found no difference in the 30-day mortality rates.[37] Observations such as these are clearly based on institutional experience, and training of community urologists to perform partial nephrectomy with low risk of morbidity remains a challenge.

OPEN PARTIAL NEPHRECTOMY: INCIDENCE

Classically, the critical technical challenge of partial nephrectomy has been balancing vascular control to reduce the risk of significant intraoperative hemorrhage against the risk of ischemic injury resulting from prolonged clamping. In most open series, hemorrhage has been the most common intraoperative complication.[39–42] The reported incidences of other significant postoperative complications include those of urinary fistula (0–17.4%), acute renal failure (0–26%), and postoperative bleeding (0–4.5%).[40–45]

In the early experience with open partial nephrectomy, reported complications were high, at ≤30.1% in one series. In that series, hemorrhage was the fourth most common complication, whereas acute renal failure was more common, occurring in 42.3% of patients.[7] In preventing bleeding and renal dysfunction, the surgeon's challenge is to balance efficient reconstruction with as minimal an ischemic injury as possible. Recognizing the deleterious effect of prolonged arterial clamping on renal function, surgeons have adopted a more permissive bleeding strategy and improved reconstructive techniques. With the increased experience of the surgeons, complications of open partial nephrectomy have declined; in a series comparing 1049 consecutive open radical or partial nephrectomies, complications of partial nephrectomy occurred in 9% of patients including urinary fistula (5.5%), acute renal failure (1.3%), perinephric abscess (1.1%), pneumothorax (0.8%), and retroperitoneal hemorrhage (0.8%).[46] Thompson and colleagues,[47] when comparing two groups of patients operated before and after 1995, reported an incidence of hemorrhage of 1.5% and 1.2%, respectively. The incidence of acute renal failure was also much lower (3.8% and 1%, respectively); dialysis was required in only 2% of those operated before 1995 and in 0.6% of those treated thereafter.[47] Urinary fistula or leak has also been a historically frequent complication in some early series (57.6%),[7] whereas in a retrospective review of 1118 partial nephrectomies at one institution, urinary leak was observed in 52 patients for a rate of 4.4%.[48] Clearly, the learning curve of partial nephrectomy has reduced morbidity.

Van Poppel and colleagues[40] prospectively compared the complications of nephron-sparing surgery and radical nephrectomy in a phase III multicenter trial. These investigators found in the nephron-sparing group a rate of severe hemorrhage (defined as blood loss >1 L) of 3.1% and urinary fistula of 4.4%, whereas in the radical nephrectomy group severe hemorrhage was seen in only 1.2%.[40] Reoperation for complications was necessary in 4.4% of the nephron-sparing group and in 2.4% of the radical nephrectomy group.[40] As such, partial nephrectomy has been considered safe and desirable, despite a higher rate of perioperative and early postoperative complications, given the potential benefit of preserving the renal function.[40] We have experienced an extremely low rate of complications

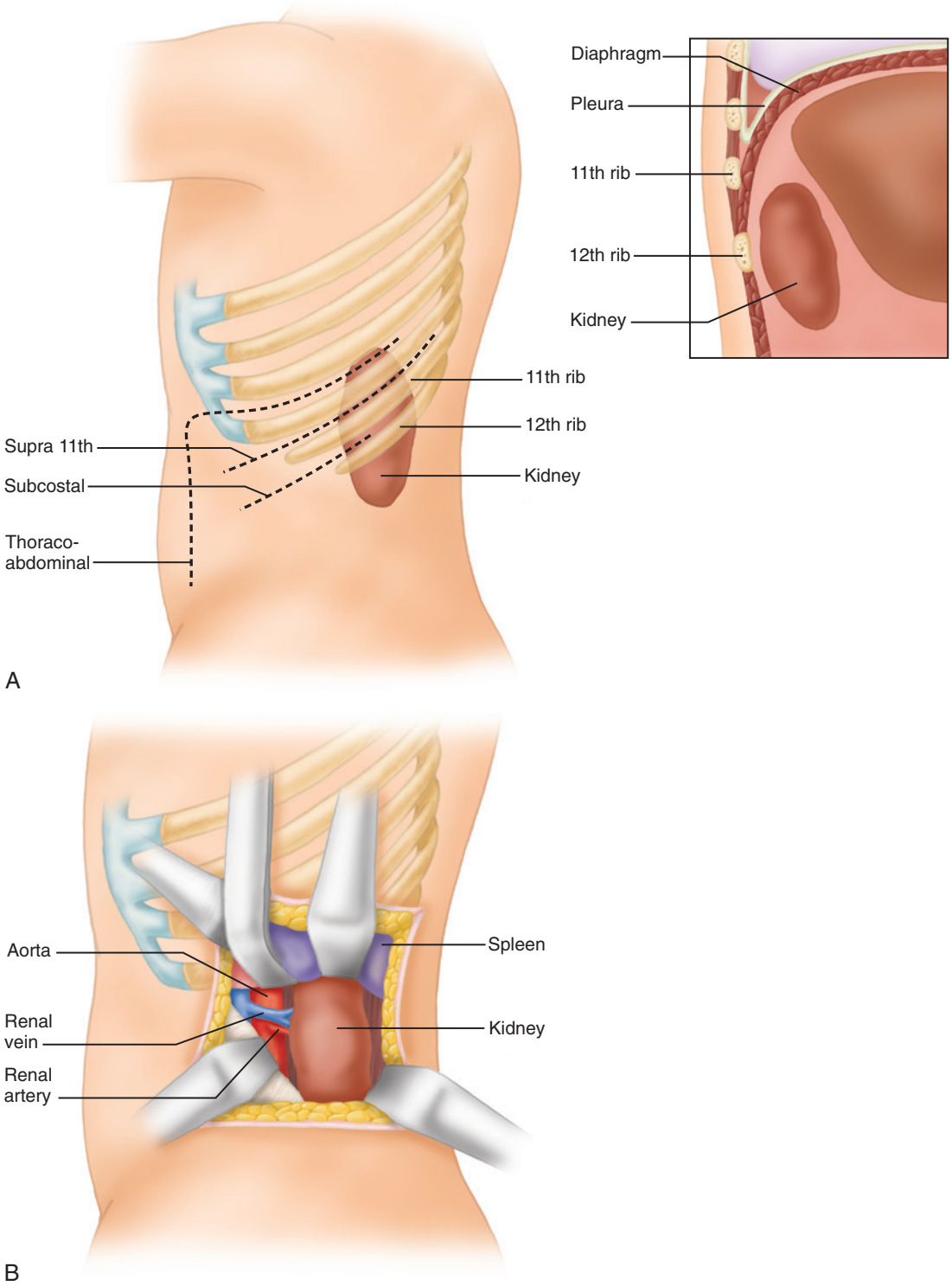


Figure 38.3 Flank incisions can be performed at a number of the intercostal spaces, with or without rib resection (A). In performing a flank incision, the risk of pleural injury increases with decreasing intercostal level, due to the pleural anatomy (inset, A). In a thoracoabdominal approach, the pleura and adjacent peritoneal cavity are intentionally entered. In exposing the kidney through a flank approach (B), intraperitoneal structures such as spleen and liver are not directly observed, but can be harmed by retraction injury. The pancreatic tail and splenic hilum are evident on the left (B), and the duodenum and vena cava are evident on the right. (From O'Malley RL, Godoy G, Taneja SS. Radical nephrectomy for localized renal cell carcinoma. In: Renal Cell Carcinoma. Campbell SC, Rini BI, eds. Shelton, CT; BC Decker; 2009.)

with contemporary partial nephrectomy by adhering to the specific technical concepts outlined later in this chapter. With careful attention to detail, partial nephrectomy can be very safely performed for most patients with early-stage renal tumors.

Specific Complications

POSITIVE MARGIN

Oncologic efficacy in renal cancer relies on a negative tumor margin during partial resection. Although investigators have demonstrated that the thickness of the margin does not appear to be important in predicting recurrence-free survival, a negative margin remains essential.[49] Simple enucleation of the tumor is certainly technically the simplest approach, but in our opinion it increases the likelihood of microscopic residual disease.

Planning the line of renal incision is heavily dependent on the tumor position and the extent of subcortical tumor. Tumors that are predominantly exophytic can be incised in a shallow incision around the circumferential base of the tumor. Tumors that are predominantly endophytic require true resection of a segment of the kidney to ensure an adequate margin. We have found the technique of intraoperative ultrasound most useful for mapping the line of renal incision during both open and laparoscopic partial nephrectomy (Fig. 38.4). The ultrasound probe is passed over the kidney from normal cortex toward the center of the tumor. Radial passes of the ultrasound probe allow mapping of the subcortical extent of the tumor. The line of renal incision is then planned on this basis.

During excision, arterial ischemia is useful in allowing direct visualization of the renal incision as it progresses. This feature is perhaps most important in laparoscopic partial nephrectomy because tactile feedback is less available to assess the surgeon's position in the kidney relative to the tumor. Incision into the tumor, or too close to it, can be redirected by a repeat incision at a greater depth starting 1–2 cm proximal to the leading edge of the incision. We have used visual landmarks in the kidney to guide the adequacy of our renal incision during laparoscopic partial nephrectomy. For example, if a tumor is radiologically positioned within 10 mm of the renal sinus or collecting system (Fig. 38.5A), then visual entry of these structures confirms the adequacy of the margin (see Fig. 38.5B).

Frozen section analysis of shaved margins is widely used to confirm the adequacy of the incision and, although this analysis may reassure the surgeon and patient, it is likely inaccurate in predicting oncologic efficacy. Sampling error and artifactual expansion of the defect during incision render this technique of margin analysis of little value.

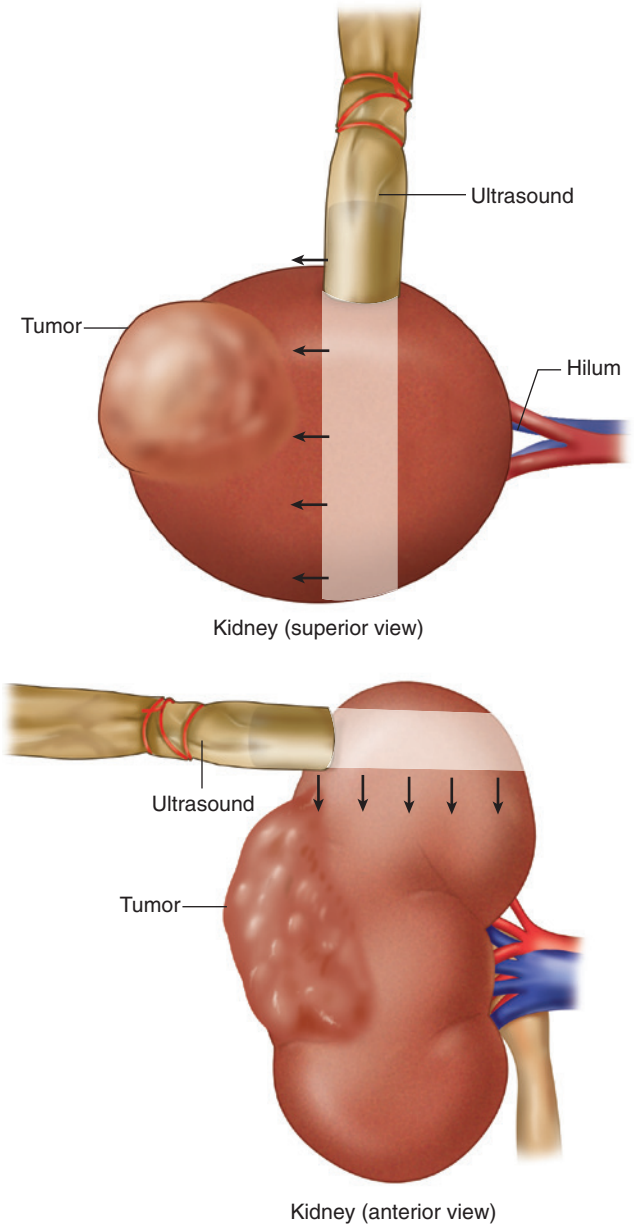


Figure 38.4 In mapping a tumor by ultrasound scan, the probe is passed across the tumor in each direction (arrows point in the direction of the probe movement) to determine the extent of subcortical tumor and to ascertain the optimal line of incision. Tumor can often extend tangential or lateral to the visible exophytic component of the tumor. The probe can be passed across the tumor in radial or perpendicular lines (like the spokes of a wheel) to assess the extent of tumor fully.

BLEEDING

Because partial nephrectomy requires transection of multiple blood vessels during renal incision, it is perhaps intuitive that bleeding is a potential consequence. Bleeding can occur intraoperatively, immediately postoperatively, and at a delayed interval up to several days or weeks after the surgical procedure. Intraoperative bleeding usually occurs from the cut parenchyma, but it can occur from the hilum if the vessels are not carefully dissected during exposure. Preoperative knowledge of the individual renal vascular anatomy is essential in this regard. Bleeding has generally been feared in partial nephrectomy. For large and central tumors, selective embolization or extracorporeal resection of the tumor followed by autotransplantation has been performed, in an attempt to provide clean margins with limited blood loss. In the contemporary era, such techniques are generally not necessary if one adheres to basic tenets of vascular control and renal reconstruction.

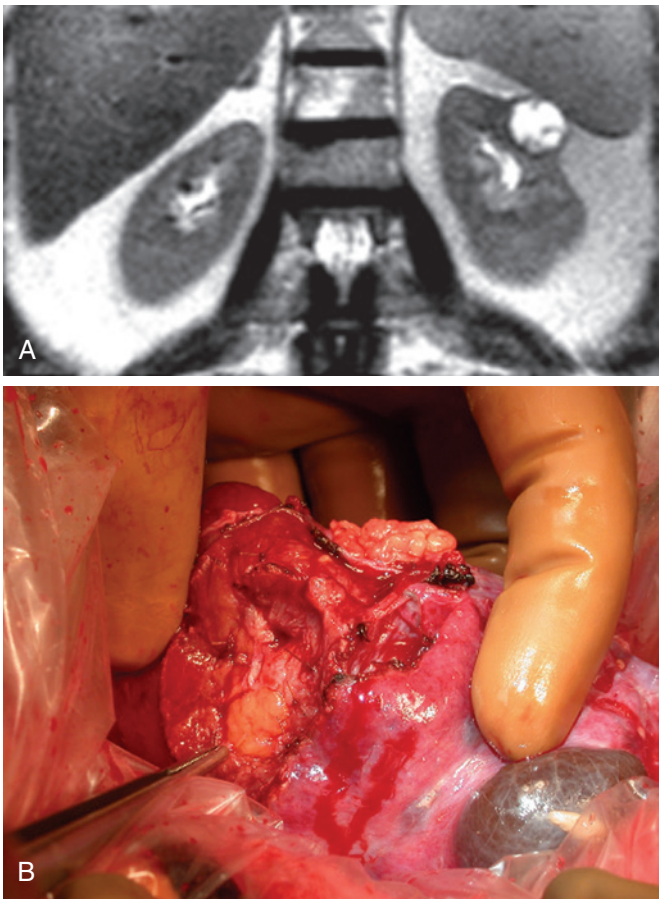


Figure 38.5 On observing the position of a tumor to be within 10 mm of the renal sinus (A), exposure of the sinus during resection (B) is essential to ensure adequacy of the margin.

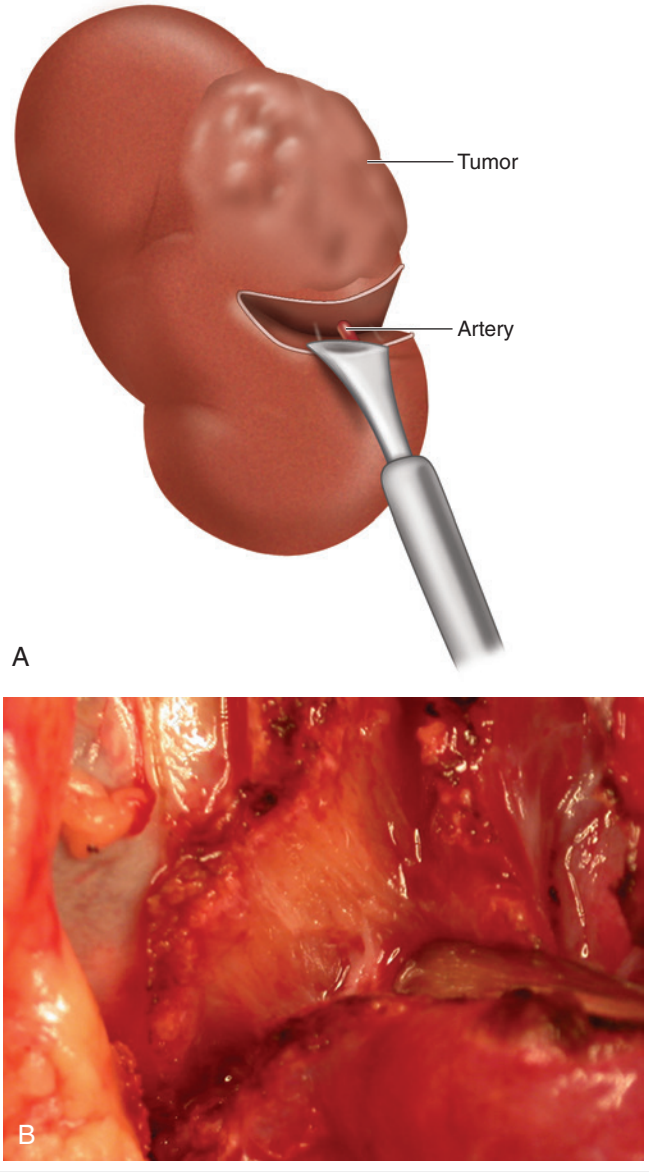


Figure 38.6 Separation of the renal parenchyma with a Freer instrument (A) allows visualization of arterial branches as they enter the specimen (B). On recognition of the vessel, it is directly suture ligated, thereby avoiding placement of deep sutures that may inadvertently injure or ligate a more proximal branch point of the vessel or adjacent vessels. (B, From Nieder A, Taneja SS. The role of partial nephrectomy for renal cell carcinoma in contemporary practice. Urol Clin North Am. 2003;30:536.)

The fundamental tenets of renal reconstruction are as follows:

1. Closure of the collecting system
2. Suture or coagulation control of small transected intraparenchymal vessels
3. Prevention of retraction within cut large central blood vessels
4. Compression of the defect to aid in venous tamponade.

A variety of tools and techniques can be employed for each tenet, but with attention to each, good outcomes can be achieved.

Parenchymal bleeding during resection is usually handled by clamping of the renal artery or vein. In most open partial nephrectomies, arterial clamping is adequate because venous tamponade through hilar stretch and manual compression is easily achieved. Brisk bleeding on renal incision despite clamping can indicate a missed renal artery, and if it is not easily identified, a hilar cross-clamp can be placed during both open and laparoscopic procedures. When performing this maneuver on the left side, the position of the aorta, adrenal, pancreas, and superior mesenteric artery should be known before the clamp is placed. On the right, avoidance of the duodenum and porta hepatis is essential. If brisk bleeding is noted with the venous clamp in place, then venous hypertension resulting from continued arterial inflow should be suspected. Removal of the venous clamp can reduce bleeding in these cases.

Numerous techniques exist for repair of cut renal vessels. Direct suture ligature with 4-0 absorbable sutures is generally preferred. We find it most effective to identify vessels during renal parenchymal incision and suture ligate them before division. The renal parenchyma is separated with a small Freer instrument (Fig. 38.6A), and on identification of the vessel (Fig. 38.6B), a direct suture ligature is placed and the vessel is divided with tenotomy scissors. In this fashion, the line of resection can be controlled and redirected (Fig. 38.7).

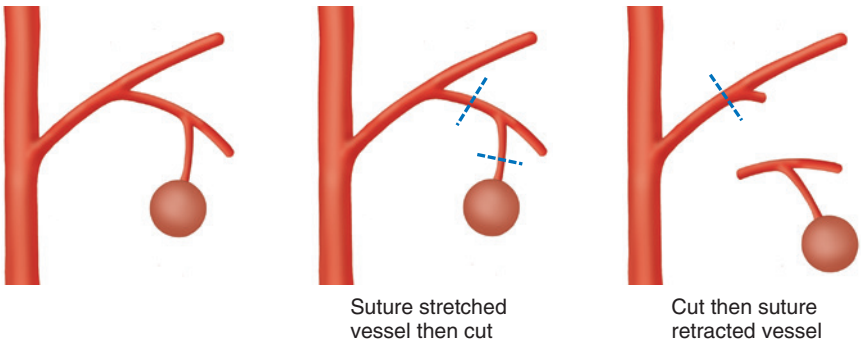


Figure 38.7 By ligating and incising small vessels entering the partial nephrectomy specimen, while they are exposed and stretched from the parent vessel, one can avoid injury to deeper vessels (thereby minimizing radial infarct) and have directional control of the depth and direction of the incision.

If brisk bleeding occurs after removal of the arterial clamp, one should again consider the possibility of venous compression or twisting of the renal pedicle, thus impairing venous outflow. If the vein is not compromised, then suture repair of bleeding should be performed while one manually compresses the defect. Reclamping of the artery should be avoided because of the increased risk of ischemic injury following reperfusion.

In cases of immediate postoperative bleeding, initial management should be conservative with transfusion, bed rest, and serial monitoring of hematocrit. Expanding retroperitoneal hematoma can worsen bleeding through stretch of the renal defect. Therefore if multiple transfusions are required, hemodynamic instability is noted, or the hematocrit is not responsive to transfusion, then one should give early consideration to angiography and selective embolization. In these patients, unlike in renal trauma, attention must be focused on the resection bed in which any visible vessels can be embolized, even if they are not actively bleeding. Intermittent hemorrhage is common, and bleeding may not actually be seen on angiography.

In patients with delayed bleeding (hematuria or flank hematoma) following discharge from the hospital, early angiography should be performed given the high likelihood of arteriovenous fistula or pseudoaneurysm. If the index of suspicion is low, or if the bleeding is minimal and the patient is hemodynamically stable, then one could first perform a duplex ultrasound scan (see Chapter 34, Fig. 34.6) or magnetic resonance angiography (MRA) because these techniques are less invasive. If an abnormality is not noted and bleeding persists, then angiography would be required anyway. Selective angioembolization is extremely effective in the management of these complications.[50] We have on occasion seen delayed hematuria resulting from decompression of an extrarenal hematoma through the collecting system. In these cases, a small, fluid-filled defect (closed urinoma) is noted at the resection bed on an MRI urogram.

INFARCT

In performing partial nephrectomy, preservation of the vascular supply of the retained segments of kidney is essential to avoid renal infarction. Although the functional significance of infarct is not known, certainly infarcted tissue likely decreases the preserved renal reserve over time. Large infarcted segments can result in renin-mediated hypertension, and if a large portion of the repaired collecting system loses blood supply, this situation can promote leakage.

Avoiding infarct again relies on knowledge of renal arterial anatomy. Given the end-arterial nature of renal blood flow, maximizing proximal vascular preservation should be the goal of resection. In approaching polar lesions, straight rather than tangential amputation is desirable, but if the lesion is primarily located within the anterior or posterior segmental vasculature, then a significant amount of parenchyma can be preserved through a tangential cut. Within the anterior and posterior segment, we find that starting the parenchymal incision away from the hilum and cutting toward the center of the kidney will allow identification of arterial branches as they enter the specimen, thereby avoiding radial infarct (Fig. 38.8). We find that starting the incision from the hilum and working outward results in a higher likelihood of injury to main branches and thereby promotes additionally infarcted kidney (Figs. 38.9A–D).

On separation of renal parenchyma along the planned line of incision, individual vessels are identified as they enter the specimen, are suture ligated, and are transected sharply to avoid the necessity for deep suture placement for retracted blood vessels (see Figs. 38.6 and 38.7). This technique is more difficult to recapitulate in laparoscopic surgery, and as such, the likelihood of radial infarct is higher in laparoscopic partial nephrectomy owing to the suturing techniques typically used in the laparoscopic procedure. We have adapted a modified suturing technique (described in Chapter 34) to reduce the likelihood of major infarct or vascular complication.

The general management of infarct is observation. In patients with severe hypertension or persistent leak resulting from infarcted kidney, nephrectomy should be performed.

URINE LEAK

Urine leak rates reported in the urologic literature depend on the operator's definition. This definition has varied widely from leakage for >72 hours to leakage persisting for >3 months postoperatively. We generally define urinary fistula following partial nephrectomy as urine leakage persisting for >4 weeks after the surgical procedure. Nonetheless, any duration of postoperative urine leak must be

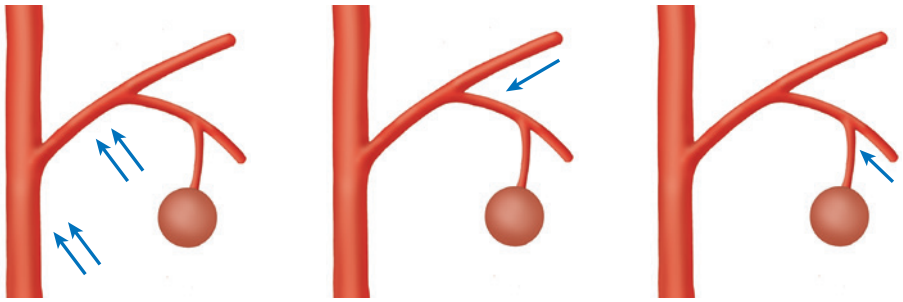


Figure 38.8 Partial nephrectomy incisions carried outward from the hilum (double arrows) often injure larger blood vessels feeding renal parenchyma beyond the planned resection. As a result the risk of radial infarct, or adjacent segmental infarct, is relatively high. Cutting toward the hilum (single arrows) allows incision of only those vessels that are feeding the resected parenchyma as they are encountered, resulting in a lower risk of radial infarct.

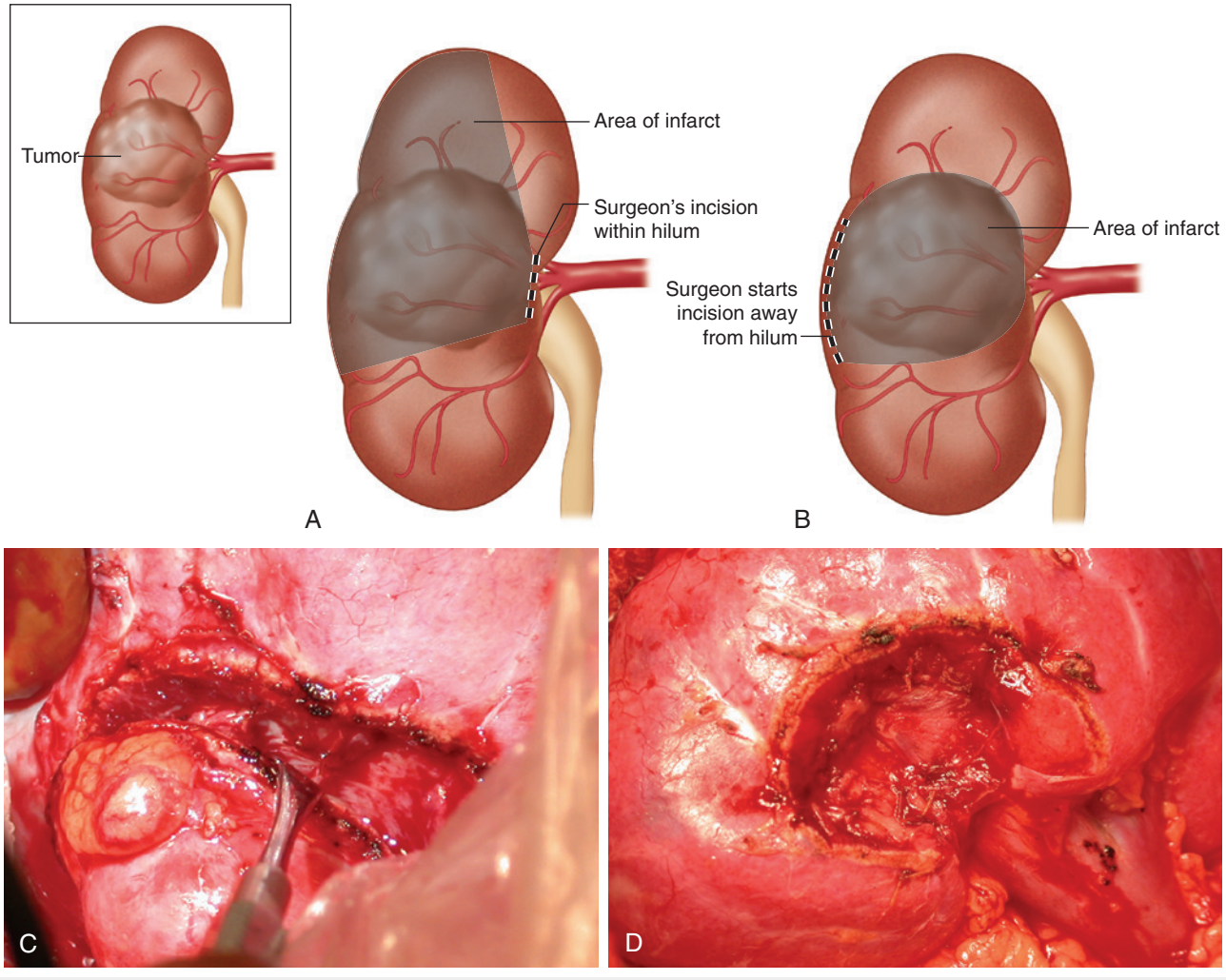


Figure 38.9 The direction of incision can influence the likelihood of injuring arterial branches that feed the residual kidney. As arteries and more proximal branch points are present in the hilar region, we generally prefer to start resection on the side of the tumor opposite the hilum. This is particularly relevant when operating in the anterior or posterior segment. A, If the incision is carried out from the hilum, infarct radial to the defect can often be seen. B–D, When starting the resection away from the hilum, larger central vessels are preserved and the surrounding kidney remains well perfused.

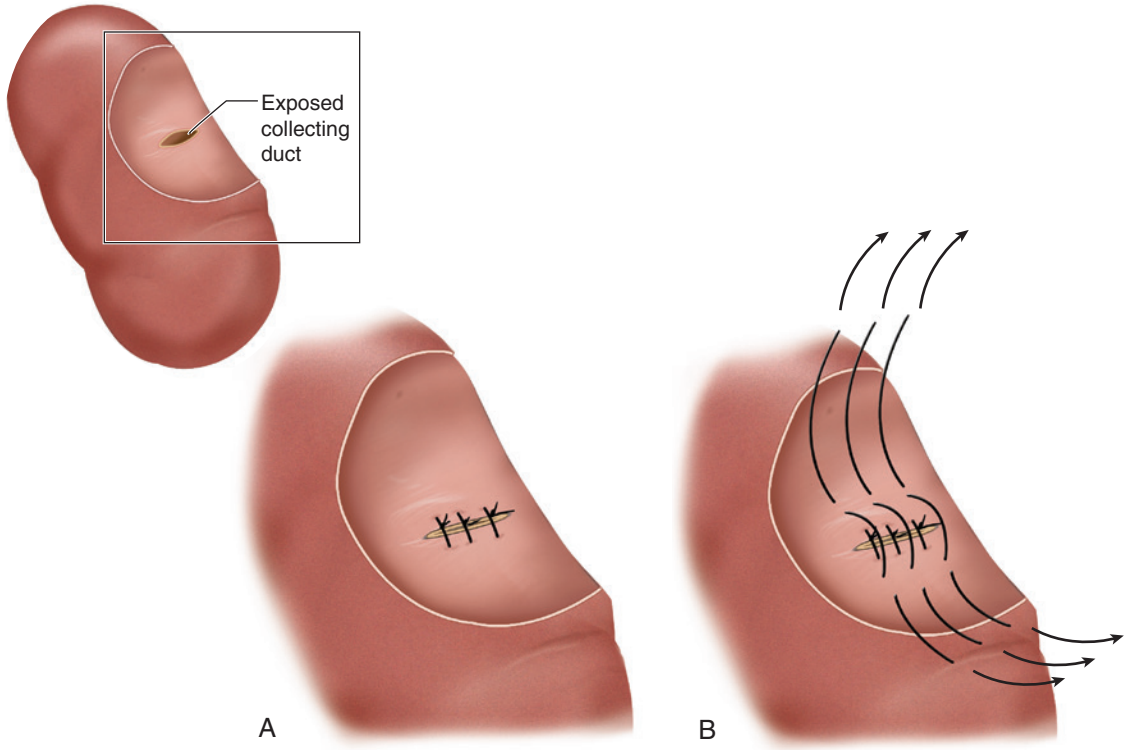


Figure 38.10 Two-layer collecting system closure involves two interrupted layers of absorbable suture. The first layer (A) incorporates the edges of the collecting system, whereas the second layer (B) attempts to imbricate normal renal parenchyma to remove tension from the first line. The use of interrupted rather than running suture reduces the likelihood of tearing the collecting system with the suture.

appropriately managed by the surgeon. Simple principles of drainage, prevention of infection, and avoidance of ureteral obstruction generally allow resolution of the leak. Management of urine leak following partial nephrectomy is additionally discussed in Chapters 13 and 34.

Careful closure of the collecting system generally prevents urine leak. In cases of large resection bed, or in tumors resected from the anterior or posterior segment with tangential renal incision, small calyceal injuries may not be identified, and these are often the site of persistent leak. In general, meticulous closure of the collecting system is performed with a layer of interrupted absorbable 4-0 braided sutures. This stage is followed by a second layer of imbricated sutures that attempt to pull the parenchyma together around the defect and thereby reduce tension on the primary closure (Fig. 38.10).

Two modifications of technique have greatly reduced our leak rate with open partial nephrectomy: (1) retrograde instillation of methylene blue through the renal pelvis and (2) the use of a layer of tissue adhesive over the closure. The use of tissue adhesive is most important in laparoscopic partial nephrectomy because small caliceal injuries are often difficult to identify. We have adopted a standardized technique of infiltrating Gelfoam (Pfizer Inc., New York) with fibrin sealant (Tisseel, Baxter International Inc., Deerfield, Illinois), molding it to the resection defect, and then activating it through infiltration of thrombin. Additional hemostatic materials are packed into the defect, and then the kidney is folded over the materials using horizontal mattress sutures of 3-0 absorbable nonbraided suture anchored to the surrounding renal capsule.

Urine leak presents in one of two ways. Early leaks often become evident in the recovery room and persist, whereas delayed leaks manifest 5–14 days postoperatively and may become symptomatic. It is not clear whether most delayed leaks were simply unrecognized early because of inadequate drainage and lack of symptoms. The old tenet that urine leakage frequently occurs in the first 24–72 hours but then resolves is not entirely true. In fact, most renal reconstruction for elective partial nephrectomy should be watertight. Early leakage generally indicates poor collecting system closure or unrecognized collecting system injury, and in our experience this leakage rarely stops within the first few days.

Early leak is suspected if drainage of >30 to 40 mL per shift is noted >48 hours after the surgical procedure. Large-volume drain outputs within the first 24 hours may lead one to suspect leak, but intervention is not required unless infection is noted, serum creatinine becomes markedly elevated because of reabsorption, or the patient has no urine output (solitary kidney). In these cases, renal obstruction may be suspected and early imaging is advised. Urine leak beyond 48 hours is confirmed by measurement of drainage creatinine level relative to serum. If the drainage is pure urine, creatinine levels will generally be >30 mg/dL. When the drainage creatinine is even moderately higher than that of the serum, then at least part of the draining fluid is urine and a urine leak is likely present. Minimal creatinine elevation may suggest a resolved urine leak with some dilute urine still in the retroperitoneum. After leak confirmation, we generally perform an immediate ultrasound scan or noncontrast CT study for assurance that the drain is

properly positioned, that no undrained urinoma is present, and that the kidney is well drained.

If all these tenets are met, the patient is discharged home with prophylactic antibiotics and a drain in place. Patients are monitored weekly with electrolytes and renal ultrasound studies to rule out worsening urinoma or drain migration. In cases of undrained fluid, the drain is repositioned to sit immediately adjacent to the leak point. This maneuver can be facilitated by contrast CT with delayed cuts. Ideal drain placement is immediately adjacent to the kidney to allow a drain tract to form. In cases of high-output leak, the drain can be converted from suction to gravity, but a follow-up ultrasound scan within a few days is warranted to rule out a secondary fluid collection.

Presentation of delayed leak is usually the result of flank pain, fever, or drainage from an incision. In a patient with fever, evaluation should include a complete blood count with manual differential, blood and urine cultures, and a chest radiograph to identify other potential sources of infection. CT with intravenous contrast should include delayed images to identify urinary extravasation, provided renal function is acceptable for receiving iodinated contrast. Ultrasound can alternatively be used to identify a perirenal fluid collection. Before percutaneous drainage, broad-spectrum antibiotics should be administered. The drain is best positioned immediately adjacent to kidney, but in cases of infection, maximal drainage is paramount to allow defervescence, and this may be best achieved with the patient in the most dependent position.

In the absence of infection, similar evaluation of renal function and imaging to identify fluid collections should be performed. On percutaneous drainage, the fistula output may be quite high initially because of the presence of a large potential space outside the kidney. Maximal kidney drainage is necessary to promote antegrade drainage over time. In general, a ureteral stent is not necessary unless evidence indicates ureteral obstruction, blood clots or debris within the collecting system, or a very large collecting system opening. In our experience, stents often worsen the leak initially, possibly as a result of reflux. It is essential to have a concomitant urethral catheter in place while the leak is perpetuated, particularly in a man with high-pressure voiding. We have generally avoided stent placement unless absolutely necessary because most leaks will close with prolonged drainage.

Resolution of urine leak generally requires scarring in of the potential space around the kidney. This occurs as scar tissue fills in around the drain forming a drain tract. We generally prefer to leave the drain on gravity drainage to promote antegrade urine flow within the collecting system. On converting to gravity drainage, a follow-up ultrasound scan within 36–48 hours will confirm that no urine collection has formed around the kidney or drain tract. If it has, then the drain should be returned to suction. Urine collections prevent the formation of a drain tract and delay leak closure. Over a period of 2–4 weeks, if properly drained, a drain tract should have formed, and on confirmation of the absence of urinoma, the drain can be advanced back 2–3 cm to allow the tract to close between the tip of the drain and the kidney. Every 48–72 hours, the drain can be pulled back another 2–3 cm until it is removed. During this time of drain advancement, one should monitor for urinoma formation and fever, a finding suggesting recurrence of the urinoma within the drain tract. In cases of high drain outputs (>300 mL/24 hours) more prolonged observation (≤12 weeks) may be necessary before attempting drain advancement. Low-output leaks require minimal observation before closure can be achieved. In this regard, closure of a leak is an active process initiated by the surgeon rather than a passive physiologic process.

Urine leak can also result from ureteral injury. Excessive dissection of the renal pelvis, the lower pole of the kidney, and the proximal ureter should be avoided because it can cause devascularization, ischemia, and necrosis with subsequent fistula formation in the dissected segment. On completion of the procedure, fat should be interposed between the lower pole of the kidney and the upper ureter to avoid adherence, scarring, and subsequent stricture of the ureter.

RENAL FUNCTION

Measuring renal functional outcomes after elective partial nephrectomy is most difficult given the compensatory ability of the remaining kidney. Conventional beliefs have been that renal dysfunction following partial nephrectomy is related to the length of renal arterial clamping and the amount of parenchyma resected. In truth, many factors may influence the function of the operated kidney including intraoperative blood pressure variations, fluid resuscitation during the case, and aggressive handling of the kidney. Intraoperative blood loss may result in a higher risk of renal dysfunction because of the possibility of hypotension and reduced tissue oxygenation. When operating on an individual with two kidneys, the risk of postoperative azotemia and the necessity for dialysis depend on the functional reserve of the remaining kidney. Patients with diabetes, hypertension, and known vascular disease are more likely to have transient azotemia postoperatively. Individuals with a solitary kidney are also affected by these factors, but clearly, the risk of azotemia is more strongly affected by renal arterial clamping than in patients with two kidneys and normal renal function.

In patients with bilateral functioning kidneys, the reported rate of acute kidney injury after open surgery has been 4%,[51] whereas chronic kidney disease has been reported to occur in 2–8% of patients.[47,51] Similar patients in laparoscopic series were shown to have negligible rates of renal dysfunction.[52–54] In patients with solitary kidneys, the rates of acute kidney injury after open procedures are more evident, ranging between 13% and 38%, with chronic kidney disease occurring in from 3% to 30% of these patients.[45,55,56] In a series of 103 partial nephrectomies in a solitary kidney, Ghoneim et al. reported that eight patients developed acute kidney failure, but nonmodifiable factors such as age and preoperative eGFR predict long-term postoperative eGFR, rather than modifiable factors such as ischemia time.[57] In laparoscopy series, these data have not been consistently reported. Analyzing an initial cohort of 430 patients who underwent laparoscopic partial nephrectomy at the Cleveland Clinic, Gill and colleagues[58] observed that in 22 cases with solitary kidneys and two of which electively converted to an open procedure, a single patient (4.5%) required temporary dialysis and the chronic kidney disease incidence rate was 13%.

Several maneuvers to reduce renal ischemia have been proposed. The use of an osmotic diuretic, such as mannitol, immediately before and shortly after clamping of the renal artery is thought to reduce the accumulation of free oxygen radicals in the tissues. Similarly, cooling of the kidney during ischemia is believed to reduce the likelihood of tissue injury. During open partial nephrectomy, we have used both these maneuvers. The kidney is placed within an intestinal bag with the opening loosely cinched around the renal pedicle. On ice slush packing, the bag serves to hold the ice to the renal surface. After clamping, a period of 5–10 minutes is necessary to reach the nadir core temperature within the kidney. We generally begin to operate on the kidney during this period to reduce total ischemia time, but other surgeons advocate waiting a full 5 minutes before renal incision.

In general, we do not clamp the renal vein because stretch of the pedicle usually sufficiently reduces venous backflow. Investigators have suggested that retrograde circulation of venous blood may allow low-level tissue oxygenation in the setting of arterial clamping. This possibility has been suggested for laparoscopic partial nephrectomy as well.[59]

An alternative to the use of vascular clamping is manual compression of the renal parenchyma. This technique is quite effective in open partial nephrectomy, particularly for polar lesions. In laparoscopic surgery, the technique can be applied through hand assistance, but this approach is more cumbersome because one-hand suturing is required. Even if the renal vessels are not clamped, they should be fully dissected in case of the need for urgent clamping. Surgery can then be performed by squeezing the renal parenchyma with the hands and using only enough pressure to control the bleeding.

Because of the increased risk of azotemia in the setting of a solitary kidney, we generally avoid arterial clamping in these patients whenever possible.[35] In most cases, this situation requires open surgery, but in the case of small exophytic tumors, a laparoscopic approach with no arterial clamping can be considered.

Postoperatively, attention should be given to avoiding or minimizing nephrotoxic or harmful medications such as angiotensin-converting enzyme inhibitors, nonsteroidal antiinflammatory drugs, and aminoglycosides. Individuals at high risk, including those with solitary kidney, large (>50%) renal resections, prolonged ischemia times, preexisting renal insufficiency, and severe vascular disease, should be prepared mentally for the possibility of temporary or even permanent hemodialysis.

REOPERATION

Urine leak rarely requires reoperation, but in cases of persistent ureteral obstruction perpetuating the leak, recurrent abscess, or severe intraperitoneal leak (laparoscopic), a repeat operation may be necessary. Obstruction may be addressed by temporary stenting maneuvers, or reconstruction if it is clearly the cause of recurrent or persistent leak. In cases of refractory leak, either due to persistent obstruction or renal infarct, nephrectomy is generally performed, particularly if the original procedure was elective in nature. Reoperation for bleeding is required when angiographic techniques fail to control postoperative bleeding. In most cases, reoperation for leak or bleeding results in nephrectomy.

Conclusions

Partial nephrectomy for tumor resection is an increasingly important technique for practicing urologists to master. The long-term benefits may be greater than initially perceived. Careful preoperative imaging, knowledge of renal anatomy, attention to patient- and tumor-related risk factors, and meticulous surgical technique are essential for achieving good surgical outcomes. Complication rates should be acceptably low if following fundamental tenets of surgical technique.

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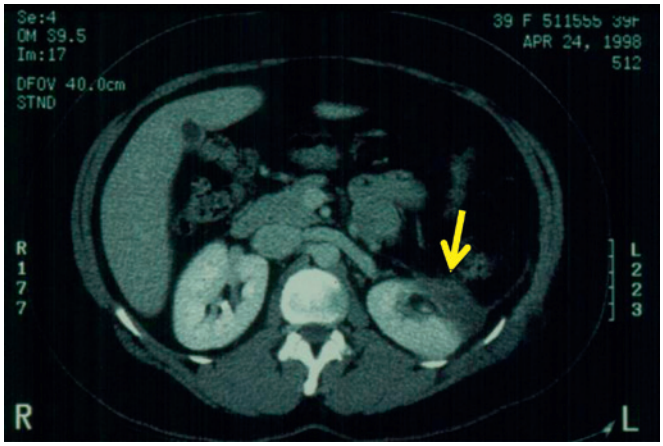
Chapter 38 Questions

1. A 63-year-old woman presents with bright red hematuria and passage of clots 15 days after uncomplicated right partial nephrectomy for a 3.7-cm tumor. What is the best diagnostic study?
   a. Cystoscopy
   b. Retrograde pyelogram
   c. Renal ultrasound
   d. Renal angiography
   e. Computed tomography

2. A 52-year-old woman has a 6-month surveillance MRI after an elective partial nephrectomy (Case Fig. 38.1). What is the most likely sequela of this finding?
   a. Recurrent infection
   b. Renal insufficiency
   c. Recurrence of cancer
   d. Hypertension
   e. Hematuria

3. In preparing the kidney for a right open partial nephrectomy resection of a 3.2-cm upper to midpole tumor through a flank incision, a polar artery is observed coursing into the right upper pole. What is the next step?
   a. Mobilization of the polar artery to aortic insertion
   b. Division of the polar artery
   c. Selective ischemia of the polar artery
   d. Pedicle clamp
   e. Extend to a subcostal transperitoneal incision

4. A 47-year-old man has a 3-cm left renal tumor located in the posterior upper pole. He has a history of inflammatory bowel disease with previous small and large bowel resection, temporary colostomy, and colostomy takedown at age 41. The best surgical approach is:
   a. Subcostal open
   b. Mini-flank open
   c. Flank open
   d. Transperitoneal laparoscopic
   e. Transperitoneal robotic-assisted



Case Figure 38.1

5. A 62-year-old woman has a left renal mass measuring 4.8 cm noted on CT urogram, located over the anterior segment midpole, abutting the hilar structures. In planning her partial nephrectomy renal incision, the most useful evaluation tool would be:
   a. Retrograde pyelography
   b. Ureteroscopy
   c. Duplex ultrasound
   d. Angiography
   e. Intraoperative ultrasound

6. The typical segmental renal arterial blood supply divides the kidney into:
   a. One anterior and one posterior segment
   b. One upper and one lower pole segment
   c. Two polar, two posterior, and one anterior segment
   d. Two polar, one posterior, and one anterior segment
   e. Two polar, one posterior, and two anterior segments

7. In performing a partial nephrectomy for a tumor located 5 mm from the renal sinus, a negative margin can be assured by:
   a. Injection of methylene blue into the renal pelvis
   b. Incision into the renal sinus
   c. Biopsy of the resection bed for frozen section
   d. Not clamping the renal artery
   e. Not clamping the renal vein

8. A 69-year-old man undergoes an open partial nephrectomy through a left flank incision. His postoperative course is notable for increased drainage from the retroperitoneal drain. Assessment of the drain fluid reveals a creatinine of 34 mg/dL. The drain output varies from 100 mL to 250 mL per 8-hour shift and persists for 3 days postoperatively. The next step is:
   a. Continued observation
   b. Renal imaging
   c. Placement of Foley catheter
   d. Placement of left ureteral stent
   e. Surgical revision

9. A 53-year-old man undergoes an elective left open partial nephrectomy for a 4.1-cm upper pole renal mass. He stopped aspirin 9 days before the operation. During surgery, the renal artery is clamped, but the renal vein is not. On renal incision, brisk bleeding occurs. The position of the arterial clamp is confirmed. Hilar palpation and dissection does not reveal additional arteries. The next maneuver is:
   a. Clamp renal vein
   b. Manual compression, proceed with partial nephrectomy
   c. Intraoperative duplex ultrasound, identify additional arteries
   d. Pedicle clamp
   e. Nephrectomy

10. A 55-year-old man undergoes a complex, elective, right partial nephrectomy for a 5.8-cm renal tumor, abutting the lower pole renal sinus. He presents with fever and fluid draining from his incision 11 days after surgery. Evaluation confirms a urine leak, with a 15-cm

urinoma around the lower pole resection bed and proximal ureter. Following drainage, the leak persists, so a ureteral stent and urethral catheter are placed.The leak persists at high volume 6 weeks postoperatively, with stent, drain, and urethral catheter in place. A CT urogram demonstrates an infarcted posterior segment and lower pole, but good perfusion and function of the remaining segments. The next step is:

a. Instill sclerosing agents into the drain
b. Place an additional percutaneous drain
c. Place percutaneous nephrostomy
d. Revision of partial nephrectomy, collecting system repair
e. Right nephrectomy

Answers

1. **d.** In cases of delayed bleeding (hematuria or flank hematoma) after discharge from the hospital, angiography should be performed early because of the high likelihood of an arteriovenous fistula or a pseudoaneurysm. If there is a low index of suspicion or if the bleeding is minimal and the patient is hemodynamically stable, you could first perform a duplex ultrasound or MR angiogram, because these methods are less invasive. If an abnormality is not seen and bleeding persists, angiography would be required anyway. Selective angioembolization is extremely effective in the management of these complications.
2. **d.** The films demonstrate an infarcted anterior segment, likely due to an unrecognized ligation or injury of the anterior segmental arterial branches. In performing partial nephrectomy, injury to deep blood vessels within the kidney may result in infarction of renal tissue beyond the renal defect. Although the functional significance of infarction is not known, infarcted tissue will likely decrease the preserved renal reserve over time. Large infarcted segments can result in renin-mediated hypertension, and if a large portion of the repaired collecting system loses its blood supply, it can promote a leak.
3. **b.** Polar renal arteries typically supply a small portion of the kidney, but they greatly reduce renal mobility. In exposing an upper pole tumor, an upper pole polar artery may greatly impair the ability to expose the resection bed. Division of the artery to improve mobility is advisable.
4. **c.** The presence of dense intraabdominal adhesion is a concern in this patient given his surgical and medical history. In cases of inflammatory bowel disease, injury to the bowel risks fistula and delayed abscess formation. As such, avoidance of the peritoneal cavity is desirable in this case. While a mini-flank incision may be feasible, its anterior location requires blunt colonic mobilization and is less desirable than a posterior, traditional flank exposure given the risks of adherence of the left colon and previous anastomosis. A retroperitoneal laparoscopic or robotic-assisted approach is also reasonable, depending upon the comfort level of the surgeon.
5. **e.** Intraoperative ultrasound is primarily used for mapping of the tumor intraoperatively, rather than the identification of additional tumors, as often thought. In this case, the hilar nature of the tumor creates concern regarding the relationship of the tumor to hilar vasculature, and this requires an assessment of the deep margin of the tumor. While angiography can be helpful in understanding vascular anatomy, it is usually not necessary given the availability of high-quality CT or MRI angiography, as needed. In this case, an angiogram would not likely add greatly to the arterial phase of the CT urogram, and retrograde pyelogram would not add greatly to the urographic phase. Intraoperative ultrasound is the most helpful test in planning the renal incision line.
6. **e.** The typical segmental arterial supply divides the kidney into apical, inferior, anterior apical, anterior inferior, and posterior segments.
7. **b.** For tumors located within 10 mm of the renal sinus, entry into, and identification of, the renal sinus can ensure an adequate resection margin. Biopsy of the resection bed is vulnerable to sampling error. The renal artery should be clamped in order to provide adequate vision to ensure resection in most cases. Not clamping the artery will not increase the likelihood of a negative margin.
8. **b.** In this case, the patient has a leak of moderate volume. It is most likely to resolve with adequate extrarenal drainage, as long as renal obstruction is not present. Renal imaging is important at the point that the leak is demonstrated to be persistent. Renal ultrasound, or cross-sectional imaging, can determine the presence of hydronephrosis, perirenal urinoma, or inadequate drain placement. In the case of hydronephrosis, a ureteral stent would be placed. In the case of perirenal urinoma, an additional percutaneous drain could be considered.
9. **b.** In this case, brisk ongoing bleeding requires some definitive intervention. Clamping the renal vein would likely worsen bleeding, as the described scenario is most suggestive of arterial bleeding due to the missed arterial branch. Intraoperative ultrasound would be unlikely to identify the location of an additional artery, though Doppler may, and would likely waste time, resulting in significant blood loss. While nephrectomy is always an option, the open approach allows the luxury of manual compression of the kidney. In most cases of polar tumors, manual compression would be sufficient to allow completion of the partial nephrectomy, without clamping of the unrecognized arterial supply.
10. **b.** Large volume leaks in the setting of infarcted kidney are unlikely to resolve if collecting system necrosis occurs as a secondary sequela. In this case, the lower pole central location of the tumor makes it likely that the lower pole collecting system, and/or proximal ureter, may have become ischemic with secondary necrosis. In this case, additional drainage is unlikely to resolve the leak, and revision would be extremely difficult, with high likelihood of failure. As such, given the elective nature of the initial partial nephrectomy, a nephrectomy would be the best option.

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39 Complications of Adrenal Surgery

MICHAEL DANESHVAR and GENNADY BRATSLAVSKY

CHAPTER OUTLINE

General and Radiographic Workup and Adrenal Incidentaloma
Hyperaldosteronism
Cushing's Syndrome
Pheochromocytoma
Adrenal Carcinoma
Metastasis to Adrenal
Surgical Approaches and Intraoperative Complications
Basic Description of the Different Surgical Approaches
Partial Adrenalectomy
Postoperative Complications and Patient Management
Hyperaldosteronism
Pheochromocytoma
Cushing's Syndrome
Chapter 39 Questions and Answers

KEY POINTS

1. Management of incidental adrenal findings must be done in a stepwise fashion to properly diagnose the lesions.
2. With the advent of improved imaging techniques and laboratory tests, physicians are capable of making correct assessments and design management plans specific for suspected adrenal pathology.
3. Adrenal surgery carries a risk of various complications that can be avoided with proper preoperative preparation and intraoperative management.
4. The evolution of surgical management of adrenal masses has gradually changed from major open operation to minimally invasive laparoscopic and robotic-assisted surgery, offering improved convalescence without the morbidity of an open surgery.
5. For small adrenal masses partial adrenalectomy can offer excellent oncologic and functional outcomes and may be especially beneficial in select patients.

With the widespread use of cross-sectional imaging, the incidence of adrenal mass findings continues to increase with a prevalence of up to 4%.[1] Adrenal tumors are found in as many as 8% of autopsies.[2] While the exact size when the workup must be done is controversial, the NIH consensus and recent recommendation suggests the workup be performed for masses greater than 1 cm.[2,3] The most common scenario requiring an adrenal workup generally begins with the incidental finding of a mass on cross-sectional imaging of the abdomen or chest. In order to standardize the diagnosis and treatment of an adrenal mass, a proper workup must first be conducted (Fig. 39.1). However, there is no standardized protocol that exists and is uniform among physicians and institutions.

The initial goals of workup are based on determining if the lesion is an adenoma or not, and whether the mass is biochemically active. Functioning or biochemically active adrenal masses are those that are hormonally secreting lesions and include pheochromocytomas, aldosteronomas, and cortisol or androgen producing tumors. The nonfunctioning tumors are adrenal masses that are simply enlarged but do not have any increased hormonal activity and most commonly include lipid-poor adenomas or cysts.[4]

This chapter aims educate on the workup and intervention of adrenal masses and how to avoid the pitfalls in diagnosis and complications associated with the management of adrenal tumors.

GENERAL AND RADIOGRAPHIC WORKUP AND ADRENAL INCIDENTALOMA

The general diagnostic approach to adrenal lesions is usually based on three pillars: clinical suspicion, targeted imaging modalities, and hormonal evaluation. While history and clinical examination may provide a basis for suspicion, radiographic and hormonal evaluation should be conducted in order to categorize the lesion as likely benign or not and biochemically active or not. Clinical diagnosis and hormonal testing may require additional imaging prior to definitive treatment planning should the initial imaging be inconclusive. Prior to discussing the biochemical testing for a specific diagnosis, it is imperative to cover the available

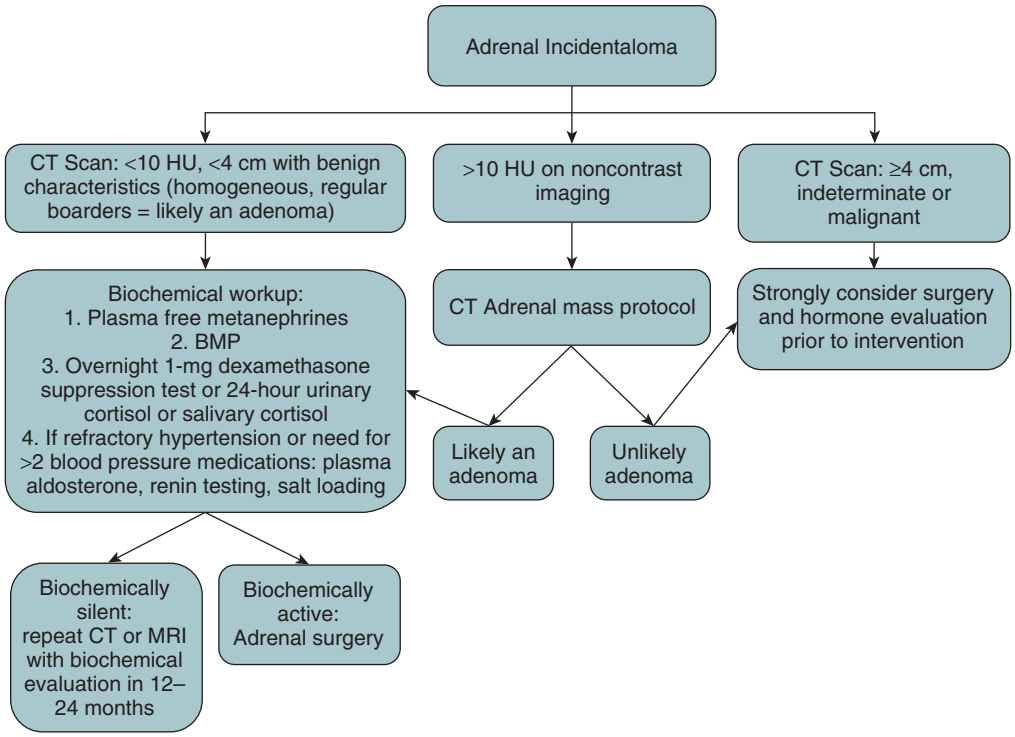


Figure 39.1 Diagnostic evaluation algorithm for a patient with an incidental adrenal finding. BMP, basic metabolic panel; CT, computerized tomography; HU, hounsfield unit.

radiographic imaging and its utility in the assessment of the adrenal lesion.

Radiographic studies play a crucial role not only in detection of adrenal lesions but also in characterizing these lesions as adenoma or suspicious for malignancy. Computerized tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) scan are usually the three imaging modalities that detect adrenal abnormality.[1] Each of the modalities specifically exploit different physiologic principles necessary in the diagnosis of adrenal masses: identification of intracellular lipid concentration in a mass, percent washout or, and the metabolic activity.[5] First of all, the size itself may be quite informative. If the lesion in question is seen on imaging as larger than 4 cm in diameter, the likelihood of malignancy is increased and intervention may be indicated simply based on the size criteria alone.[4] The rate of growth of the adrenal mass may also be informative, as benign adenomas will grow slower than malignant tumors.[6,7] As with any other tumors, consistency (cystic versus solid), shape, and contour of the tumor may be helpful, with benign lesions appearing smoother and better circumscribed compared to malignant tumors.

Among all modalities, the noncontrasted phase of CT is likely to be the most informative. In the case of attenuation of less than 10 Hounsfield units (HU) the probability of malignancy is minimal and the patient most likely has an adrenal adenoma.[8,9] If, however, attenuation of the adrenal gland on unenhanced imaging is greater than 10 HU, the index of suspicion for malignancy should be higher, and further radiographic workup should be performed. Should the patient have sufficient renal function, enhanced CT with a calculated washout will help differentiate lipid-poor adenomas from potentially more ominous lesions. A vast majority of adrenal adenomas have HU less than 10 while most carcinomas exhibit HU greater than 30 on unenhanced CT.[10,11] Of note, lipid-poor adenomas can also have values higher than 10 HU, indicating that many lesions with HU >10 are still benign.[12] Therefore an adrenal protocol CT (or alternatively MRI) is recommended.

Contrast-enhanced CT, MRI, or PET can help distinguish between benign and malignant lesions. In the case of the adrenal mass protocol CT, a noncontrasted phase is followed by contrasted phase and a 10- to 15-minute delay. In studies evaluating the rate of the enhancement loss at specific time intervals (contrast washout) the adenomatous lesions washed much faster when compared to nonadenomatous or malignant lesions. Some have demonstrated that the washout was observed at as early as 3 minutes.[5] Typically, over 50% of washout of contrast on 10-minute delayed CT is diagnostic of an adenoma.[4] Occasionally, when CT scan is indeterminate it is appropriate to utilize chemical shift MRI to further categorize the lesion.[13] Chemical shift MR imaging detects presence of a lipid within an organ and is regarded as a sensitive method for differentiating adenomas from metastases.[14,15] Typically, MR imaging is more costly and time consuming when compared to the ease of CT and is therefore utilized less often.[4] Lastly, PET scan (using fluorine-18 fluorodeoxyglucose or FDG) can be helpful in selected cases to identify the metabolic activity and exploring the differences of lower activity of benign tumors versus more metabolically active malignant lesions based on glucose utilization and differential FDG uptake.[4]

Additional PET agents are becoming useful in further workup and differentiation of adrenal masses.[16]

Ultimately, the radiographic portion of the adrenal workup will guide the index of suspicion for benign or malignant etiology. Metabolic workup will ultimately provide a more definitive diagnosis. Occasionally, however, the definitive diagnosis is only possible after surgical removal.

HYPERALDOSTERONISM

Aldosterone-producing adenomas (APAs) constitute approximately 2% of incidentally discovered adrenal masses.[12] While often nonspecific, symptoms can range from muscle cramping, weakness, headaches, and polydipsia associated with polyuria. Patients with APA may have hypertension that is refractory to treatment by multiple (usually three) antihypertensive medications. In addition, some, but not all, may exhibit hypokalemia (usually serum potassium <3.5 mEq/L) and hypernatremia.

Identification of an adrenal mass in a hypertensive patient presenting with refractory hypertension or hypertension requiring several types of medication usually leads to further workup for APA. The diagnosis of APA or hyperaldosteronism itself consists of a two-step approach with screening and confirmatory testing.[17] First, the calculated ratio of plasma aldosterone concentration (PAC ng/dL) to plasma renin activity (PRA ng/mL) is performed. To increase the specificity further, PAC to aldosterone renin ratio (ARR) can be obtained.[18,19] Since the levels of renin and aldosterone may be affected by numerous medications, it is important that the screening test is conducted properly. Several types of medications that are mineralocorticoid receptor blockers such as spironolactone and eplerenone must be stopped 4–6 weeks prior to screening.[20] When drawing blood samples for suspicion of APA, the ARR is the most sensitive test. The labs should be drawn in the morning after the patient has been out of bed for over 2 hours and seated for 5–15 minutes.[20]

After the initial plasma levels of aldosterone and renin are obtained, further testing is done by salt loading.[20] This can be performed by measuring 24-hour urinary aldosterone levels after either consuming one teaspoon of salt with the addition of salty foods for a period of 72 hours or by saline suppression testing where isotonic saline is infused at 300–500 mL/h for a total of 4 hours. Extra caution should be exercised in patients with heart failure, severe hypertension, and those who are already taking multiple antihypertensive medications. Failure to suppress 24-hour aldosterone levels to normal levels after the salt loading confirms diagnosis of primary aldosteronism.

Finally, after the diagnosis of primary aldosteronism based on clinical and laboratory tests, the treatment plan is paramount. While cross-sectional imaging (usually with CT) is quite helpful in defining the location of the adrenal nodule, adrenal vein sampling (AVS) is mandatory for lateralizing the disease and distinguishing between unilateral and bilateral processes.[21] This is done to avoid subjecting the patient to erroneous removal of a nonfunctioning adenoma on the wrong side, while the micronodular hyperplasia of the adrenal (not readily seen on cross-sectional imaging) may be producing the aldosterone. The most optimal setting to perform AVS is in the morning and in the fasting state. Failure to lateralize with the use of AVS may lead to improper surgical or medical treatment of APA. One study in particular showed that when CT alone was utilized to establish laterality without AVS, 25% of patients underwent unnecessary or inappropriate adrenalectomy.[21–23]

When the decision to operate has been made, preoperatively patients should be started on a mineralocorticoid receptor antagonist. This approach not only corrects the preoperative hypokalemia but also controls the hypertension. Finally, while working on the diagnosis of primary aldosteronism, we must also be aware that secondary aldosteronism may be seen in patients with renal artery stenosis, malignant hypertension, pregnancy, heart failure, and cirrhosis.

CUSHING'S SYNDROME

Cushing's syndrome is characterized by glucocorticoid excess and exhibits the typical signs and symptoms of hypercortisolism. From a careful history of the patient the following can be elicited: fatigue, sleep disturbances, depression, weight gain, hypertension, and easy bruising. On physical exam patients present with central obesity, facial plethora, thinned skin, acne, striae, hirsuitism, and proximal muscle weakness and wasting. Since the most common cause of glucocorticoid excess is usually from exogenous steroid intake, thorough investigation by the physician should be done to rule out potential iatrogenic sources of cortisol excess.

While clinical diagnosis is an integral part of the Cushing's syndrome diagnosis, biochemical evaluation is paramount and involves screening and confirmatory testing. There are three simple screening tests that can be used for early suspicion of hypercortisolemia. The first of these tests is the late-night salivary cortisol test used for screening Cushing's syndrome. A specimen of saliva is collected at bedtime in patients with a regular sleep pattern and tested in a laboratory. The sensitivity and specificity for diagnosing Cushing's syndrome approaches 90–95% if the nighttime cortisol levels are elevated.[24] Alternatively, the overnight 1-mg dexamethasone suppression test (DST) is used. This test is performed by administering 1 mg of dexamethasone at 11 p.m. and testing for plasma cortisol levels the following morning at 8 a.m. The DST is also used to differentiate between Cushing's syndrome and Cushing's disease (when 8 mg of dexamethasone is used).[25] The third screening tool is the 24-hour urinary free cortisol (UFC) level. Any of the above three tests must be done in a systematic and timely fashion to be accurate and avoid false results or erroneous diagnosis.

Once elevated levels of cortisol are demonstrated in the setting of Cushing's syndrome (and Cushing's disease is appropriately ruled out), proper preoperative planning is crucial. Patients with diabetes and hypertension must be managed appropriately. Because of possible immunosuppression as a result of long-standing elevated levels of cortisol, care must be taken with prophylactic preoperative antibiotics. Due to long-standing suppression of the hypothalamic pituitary axis, imaging may depict a contralateral adrenal gland that is atrophied. In all cases, a stress dose of steroids should be administered preoperatively with a careful taper.[26]

Table 39.1 The Recommended Conditions of Biochemical Testing

Patient preparation	Avoid sympathomimetic agents (including ephedrine, amphetamine, nicotine) Avoid interfering medication (including labetalol, sotalol, acetaminophen, methyldopa, antidepressants) Overnight fast, no caffeinated or decaffeinated beverages
Conditions for blood sampling of metanephrines	Supine condition, after 30 minutes' rest[a] Collection in heparinized tubes on ice Storage of plasma in freezer at –20°C if measured within 3 months
Conditions for urine sampling of metanephrines	Collection in a container without additives or eventually only sodium bisulphate Storage of urine container in a cold place Acidify urine in the laboratory to pH 4 before storing

[a]If a blood sample is taken in the sitting position and the test result is positive: repeat after 30 minutes' supine rest

(Van Berkel A, Lenders JW, Timmers HJ. Diagnosis of endocrine disease: biochemical diagnosis of phaeochromocytoma and paraganglioma. Eur J Endocrinol. 2014;170(3):R109-R119.)

PHEOCHROMOCYTOMA

Patients who present with severe, episodic hypertension, palpitations, tachycardia, anxiety attacks, weight loss, sweating and facial flushing on physical exam should be suspected to have pheochromocytoma. The patient's family history is also important as pheochromocytoma does not only occur sporadically but can be inherited or associated with several genetic syndromes, such as von Hippel-Lindau (VHL) disease, multiple endocrine neoplasia type II (MEN), familial paraganglioma syndrome, neurofibromatosis (NF-1), and succinate dehydrogenase deficiency syndrome of subunits B, C, or D (SDHB, SDHC, or SDHD).

First, biochemical evidence of the disease is confirmed with testing of plasma free metanephrines. In one study, sensitivity and specificity of this test were 96–100% and 87–92%, respectively.[27] While the plasma free metanephrines is the most sensitive test, care must be taken when collecting these samples. There are numerous pitfalls that may affect the results of the testing (Table 39.1). Usually, patients must have an IV inserted and be placed supine in a quiet room for 30 minutes. Any pain or anxiety may significantly affect the results of the test. Additionally, patients should be instructed to avoid any caffeine intake for at least 24 hours and avoid the medications listed in Box 39.1. Perhaps, the most important and common medications to remember are acetaminophen, trycyclic antidepressants and decongestants. Alternatively, (although now used less commonly) 24-hour urine collection for urine metanephrines and vanillylmandelic acid (VMA) testing can be performed. While the test is less sensitive than plasma free metanephrines, it is more specific (VMA specificity 93–97%).[27]

With a high suspicion on clinical exam and confirmation by biochemical workup, the next step in workup of pheochromocytoma is often a combination of anatomic and functional imaging. In the past, contrast enhanced MRI was the preferred method of anatomic imaging in suspected

Box 39.1 Medications That May Cause False-positive Results for Catecholamines and Metanephrines

Tricyclic antidepressants and antipsychotic agents
Levodopa
Drugs containing catecholamines
Ethanol
Withdrawal from clonidine and other drugs
Acetaminophen and phenoxybenzamine (plasma metanephrines)
Labetalol and sotalol

(From Kudva YC, Sawka AM, Young WF. The laboratory diagnosis of adrenal pheochromocytoma: the Mayo Clinic experience. J Clin Endocrinol Metab. 2003;88(10):4533-9.)

cases of pheochromocytoma for fear of inducing adrenal crisis with the use of iodinated contrast in enhanced CT scanning.[28] Now, however, CT with nonionic iodinated contrast is safe and provides excellent anatomic details. MRI (often bright on T2 sequence) is still a useful imaging modality in patients who have previous allergic responses to contrast mediums, in pregnant women, and in children being scanned.[29,30] Several functioning radiographic studies such as metaiodobenzylguanidine (MIBG) and various types of PET scans are available. Although the detailed review of every imaging modality for pheochromocytoma is beyond the scope of this chapter, care must be taken in those undergoing MIBG scanning by providing patients with super saturated potassium iodide (SSKI) drops to be taken prior to exposing patient to radioactive iodine (thyroid protective measures).

The importance of preoperative preparation for surgical treatment of pheochromocytoma cannot be overstated. It includes patient compliance, preoperative echocardiogram (to evaluate the cardiac function and rule out cardiomyopathy), and evaluation by anesthesiology team. Medical preparation involves the liberal use of α-adrenergic blockade with phenoxybenzamine 10 mg BID with a slow increase in dose over 2–3 weeks prior to surgical intervention. The recommended dose of phenoxybenzamine starts at 10 mg BID and should be titrated up to as high as 400 mg daily until the patient becomes orthostatic or profound side effects become intolerable (such as tachycardia or nasal congestion). In cases of tachycardia, beta-blockers can be added, but should only be added after the adequate alpha blockade. Metyrosine (α-methyltyrosine) 250 TID to increase to 1.5 g in divided doses can also be used as an adjunct to phenoxybenzamine in preparation for surgery. Metyrosine inhibits tyrosine hydroxylase, the rate-limiting enzyme in the catecholamine synthesis cascade. Finally, patients are also encouraged to prepare with adequate fluid and salt intake to volume expand and compensate for the vasoconstrictive effects of pheochromocytomas and intravascular volume depletion.[31]

ADRENAL CARCINOMA

Adrenocortical carcinoma (ACC) is a rare but aggressive tumor with a poor prognosis.[32] Two-thirds of all ACCs are found to be hormonally active, and approximately 25% are found to be >6 cm on diagnostic imaging.[33,34] As discussed

earlier in this chapter, when an incidentaloma is found with an attenuation of greater than 10 HU on noncontrasted CT, the suspicion for ACC should be present. The suspicion is even greater when the mass is large (>6 cm) or has attenuation of >30 HU on noncontrasted CT.[12] Clinically, patients may complain of flank pain, abdominal discomfort, or pressure with no specific symptoms due to the mass compression of adjacent abdominal structures or organs. Hormonally active tumors may present with symptoms such as virilization, hypercortisolism, or feminization. Therefore, similar to other adrenal masses, evaluation of ACC includes the assessment of hormonal activity. Biochemical workup must include thorough hormonal evaluation prior to surgical intervention as stress steroids may need to be administered preoperatively or repleted postoperatively to prevent adrenal insufficiency or addisonian crisis. On imaging studies, several characteristics of tumors may lead to higher suspicion of malignancy such as irregular tumor shape and enhancement with lack of homogeneous patterning of the tumor due to areas of focal necrosis. If there is a high suspicion for ACC, a metastatic workup is also indicated preoperatively. Preoperative planning involves an assembly of an experienced team of radiologists, surgeons, and anesthesiologists, and a great deal of planning from identifying surgical landmarks (as some tumors may invade surrounding structures or organs) to adequate vascular access and adequate amount of blood products available.

METASTASIS TO ADRENAL

One common pitfall in the workup of an adrenal mass is failure to identify metastasis from a primary tumor. Although primary adrenal masses are most common, adrenals are also a common site of metastasis.[35,36] Once metastasis is essentially ruled out, different diagnostic practices will guide a step-by-step workup of an adrenal mass (see Fig. 39.1). Conversely, a suspicion of metastasis should not preclude one from completion of biochemical interrogation of the adrenal mass. For example, one study evaluated patients with a history of primary tumors and suspected adrenal metastasis and found that as many as 24% of those adrenal masses were pheochromocytoma.[37] This further underscores the importance that any adrenal mass should have a biochemical workup.

Most Important Preoperative Considerations and Tips

1. For patients with suspected aldosterone-producing adenoma it is crucial to complete the selective adrenal vein sampling as the presence of a nodule on the adrenal and elevated levels of aldosterone are **NOT** diagnostic of laterality in patients with Conn's disease. We recommend performing selective adrenal vein sampling because the imaging may reveal an adrenal nodule that may be a nonfunctional adenoma, while the functional microadenoma(s) may be present in the radiographically normal contralateral adrenal gland. Therefore selective adrenal vein sampling is paramount in avoiding a wrong-sided surgery.
2. For patients with suspected cortisol-producing adenoma, the appreciation of long-term effects of steroid excess is crucial. Meticulous attention to preoperative blood pressure control and antibiotic administration due to the chronic immunosuppressive effects of steroid administration is essential. The most important prevention of unexpected intraoperative and postoperative complications is the preoperative administration of a stress dose of steroids as the contralateral adrenal gland is often suppressed. Careful taper perioperatively should allow for tight blood pressure control with the avoidance of an addisonian crisis while allowing the contralateral adrenal gland to regain its function and to recover from the suppression due to the steroid excess.
3. For patients with suspected pheochromocytoma the importance of preoperative blockade cannot be over emphasized. Perhaps the most important concept is that the perioperative blockade (most commonly with alpha-blockers, specifically phenoxybenzamine) should be titrated until systolic blood pressure falls below 100 or the patient becomes orthostatic and/or tachycardic. Only at this time should beta-blockade be added. Volume expansion is often done concomitantly with a high sodium diet and large oral fluid intake for the duration of the blockade. Occasionally patients have to be admitted for IV fluid hydration and blood pressure (BP) monitoring. Finally, because of the potential for catecholamine-induced cardiomyopathy, preoperative echocardiogram is recommended to obtain a baseline cardiac function as cardiomyopathy has been demonstrated to occur even in children and young adults. Preoperative knowledge of cardiac function will later help with intraoperative and anesthetic management.
4. Prior to any procedure, a conversation with the anesthesiology team is crucial so as to have appropriate drips, drugs, and expectations for the potential intraoperative complications or blood pressure issues that may arise. Our typical setup (Fig. 39.2) for expected complicated pheochromocytomas includes the following configuration and drips: vasopressin, phenylephrine, norepinephrine, esmolol, nitroprusside, and nitroglycerin. While all of these medications may not be needed, having them readily available, especially for complex patients with poorly controlled hypertension, may be life-saving. Finally, once the pheochromocytoma is removed, the team may have to recognize the earliest signs of blood pressure drop requiring the administration of pressors and boluses of IV fluids. Again, the better the preoperative blockade, the safer the operation.



Figure 39.2 Typical setup for pheochromocytoma surgery with multiple drips.

Surgical Approaches and Intraoperative Complications

Surgical complications for any operative approach or technique are diverse. The most common complications are hemorrhage, adjacent organ injury, infection, postoperative wound healing, and pulmonary problems. Surgical intervention, regardless of method of approach, requires attention to the surrounding anatomy of the adrenal gland and its vasculature. Therefore it is imperative to be well acquainted with adrenal anatomy and surrounding structures prior to surgery.

Adrenal surgical techniques have evolved with the use of laparoscopic and robotic surgery. While no technique completely avoids surgical complications, recent studies have shown that most adverse outcomes are decreased by the use of minimally invasive surgery.[38] These new techniques now serve as adjuncts to the open surgical approach used for the past several decades.[30] This section will describe the different surgical approaches and identify the most common complications faced during adrenal surgery.

BASIC DESCRIPTION OF THE DIFFERENT SURGICAL APPROACHES

Adrenalectomy can be performed in either a transperitoneal or retroperitoneal approach. The underlying pathologic process of the adrenal tumor and surgeon's preference usually dictate the different surgical approaches. Both the transperitoneal and retroperitoneal approaches can be performed via open or minimally invasive approaches. Open transperitoneal approach includes midline, thoracoadbominal, or subcostal incisions. The subcostal anterior approach is an excellent option for large tumors and offers a wide operative field favorable for large unilateral tumors.[39] It can also be used for bilateral tumors with extension by chevron incision to adequately reach both adrenal glands. The thoracoabdominal approach is the most invasive method of gaining access to the adrenals. While the thoracoabdominal approach is used for large tumors or invasive ACC, historically it has caused prolonged ileus due to intraabdominal organ manipulation, increased pain from incision location, and pulmonary morbidity necessitating chest tube placement.[40,41] Additionally, when utilizing the transperitoneal approach, irrespective of open or minimally invasive, the tail of the pancreas may be injured during dissection from the adrenal gland. This warrants placement of a drain for postoperative fluid analysis and diet modification accordingly (from low-fat diet to total parenteral nutrition (TPN) and octreotide).[42] The retroperitoneal approach is achieved via flank and posterior lumbodorsal incisions. Retroperitoneal surgery offers the advantages of less intraabdominal organ manipulation and therefore less postoperative ileus. Retroperitoneal surgery may also be advantageous in the setting of previous abdominal surgery in which adhesions may complicate or limit a transabdominal open or minimally invasive approach.[28] Of importance, when patients are obese, a flank position in both the open and laparoscopic approach will allow the pannus to fall away and thus will make incision or placement of instruments easier.[25]

With the advent of minimally invasive techniques, fewer and fewer adrenal surgeries are performed via the open approach. In a recent meta-analysis that included 600 patients from eight retrospective studies and one randomized control trial, Brandao et al. found a significantly shorter hospital stay and less estimated blood loss with robotic adrenal surgery compared to laparoscopic method.[38] Similar to the study by Brandao et al., recent studies have shown that robotic adrenal surgery is associated with less blood loss, while the surgical time is dependent on surgeon experience in relation to laparoscopic adrenalectomy.[43] Additionally, among the choices of minimally invasive approaches, some argue that a transperitoneal approach affords a larger work space with a more familiar approach to the abdomen and may permit easier removal of large masses when compared with a retroperitoneoscopic approach that offers a smaller working space with a less familiar view of the retroperitoneum as compared with the transabdominal approach.[27,29]

Nevertheless, regardless of the approach, both laparoscopic and robotic adrenal surgical techniques are safe and effective surgical options with improved outcomes of patient satisfaction, shorter postoperative hospitalization, and reduced surgical pain compared to open surgical techniques.[44,45] When comparing the two minimally invasive techniques, robotic adrenal surgery has the advantage of three-dimensional surgeon vision compared to the two-dimensional view of laparoscopic surgery, a stable surgical platform, and improved ergonomics.[46] However, robotic surgery cannot be performed without the advanced surgical training of the operator and the assistance of a robotically trained operating room team. Despite advantages of minimally invasive surgery, open technique is still reserved for large adrenal tumors or tumors with high suspicion of being ACC based on preoperative workup, especially if there is a suspicion of the adjacent organ or structure involvement. Occasionally, conversion from minimally invasive to open approach is necessary to facilitate en bloc resection of the tumor with regional lymphadenectomy and resection of any involved organs. This further underscores the importance of the surgeon's versatility in open skills (as with any minimally invasive operation). Large tumors, for example, that are concerning for ACC may require resection or partial resection of surrounding organs along the inferior vena cava.[47] Therefore, meticulous surgical planning should be conducted prior to making an incision.

PARTIAL ADRENALECTOMY

Partial adrenalectomy can be achieved by any of the above approaches used for total adrenalectomy. Recently, partial adrenalectomy has gained much popularity and attention due to its potential long-term benefits and proven functional outcomes. While initially reserved for patients with bilateral adrenal involvement or in those at risk for bilateral adrenal loss due to various hereditary disorders, new data suggest that partial adrenalectomy may be utilized for small solitary lesions in patients with a normal contralateral adrenal gland.[48] Recent reviews evaluating disease of the adrenal suggest that after the exclusion of those patients at risk for bilateral adrenal pathology due to genetic risks, the life-time risk to a contralateral adrenal is about 1%.[49] While originally performed with an open approach, recent literature

Box 39.2 Complications of Laparoscopic Partial Adrenalectomy

Total patients (%)	363 (100)
Complications	27 (7.4)
Abdominal wall laxity	5 (1.4)
Hemorrhage	5 (1.4)
Pneumonia	3 (0.8)
Pneumothorax	3 (0.8)
Wound infection	3 (0.8)
Hyperesthesia	2 (0.6)
Sepsis	1 (0.3)
Ileus	1 (0.3)
Migrated drain tube postsurgery	1 (0.3)
Omental herniation	1 (0.3)
Hypertension	1 (0.3)
Renal vein injury	1 (0.3)

(From Kaye DR, Storey BB, Pacak K, Pinto PA, Linehan WM, Bratslavsky G. Partial adrenalectomy: underused first line therapy for small adrenal tumors. J Urol. 2010;184(1):18-25.)

indicates a shift from open to minimally invasive techniques.[48] Robotic and laparoscopic partial adrenalectomy have changed adrenal surgical intraoperative and postoperative outcomes. In fact, the use of robotic surgery in partial adrenalectomy allows the surgeon to utilize the robotic arms in addition to an assistant for adequate exposure when compared to traditional laparoscopy.[50] Exposure and ability of the robot to articulate its wrists in limited space allow for minimal mobilization and manipulation of tumor during removal while likely preserving the delicate blood supply of the remnant adrenal gland.[50] Size of the tumor, timing for intervention, and location of the tumor also play a role in the decision to conduct partial adrenalectomy.[51] Box 39.2 summarizes surgical complications from partial adrenalectomy. Overall, the morbidity of partial adrenalectomy does not supersede that of total adrenalectomy with the overall complication rate about 3%.[48] One notable drawback of partial adrenalectomy is a possibility of development of a new lesion or recurrent disease. In the largest review to date that evaluated the outcomes of partial adrenalectomy, the rate of recurrence was found to be only 3%, with the vast majority of the patients not requiring chronic postoperative steroids.[48] Pedziwiatr et al. suggested that when conducting robotic or laparoscopic adrenalectomy, the risk of complications depends on many variables (not only operator and the surgical team involved), and these complications do not and should not be different for partial adrenalectomy procedures.[52] Interestingly, long-term outcomes for partial adrenalectomy are quite encouraging.[48,51] It is possible that with further acceptance of partial adrenalectomy, this procedure may become a standard of care in the majority of patients with small adrenal masses.

Most Important Intraoperative Considerations and Tips

1. In cases of right adrenal surgery we prefer to proceed with a minimally invasive transperitoneal approach because of the ease of the right adrenal gland access, familiarity of anatomy, and a larger working space. Cephalad retraction of the liver with division of the right lateral triangular ligament while the patient is in the flank position with slight Trendelenburg allows for an immediate approach to the adrenal mass. Of note, no mobilization of colon or kidney or dissection of renal vasculature is required with the first move directed toward the incision of the adventitia over the inferior vena cava (IVC). Because of the lateral decubitus positioning, the normal origin of the posterolateral short right adrenal vein shifts to a more anterolateral location, making its identification, division, and ligation quite simple. One Weck clip on each end should allow for a bloodless operation. In cases of partial adrenalectomy on the right side, the adrenal parenchyma can be clipped using Weck clips allowing for excellent hemostasis and visualization. Should any bleeding be encountered, a suture ligature can be utilized on the caval end or additional clips or even LigaSure can be applied on the side of the adrenal gland.
2. In the cases of left adrenal surgery, we also prefer the transperitoneal, minimally invasive approach. Unlike the surgery on the right side, we perform a mediovisceral rotation with mobilization of the left colon, spleen, and pancreas to allow for the visibility of the left adrenal gland. Identification of the left renal vein allows for easy and early recognition of the left adrenal vein. Unlike in the typical illustrations of the anatomy texts, there are usually more than one adrenal vein originating from the left renal vein. These can be easily ligated and divided to avoid any bleeding complications. Additional blood supply originating from the aorta, phrenics, or running within Gerota's fascia can be easily controlled using Weck clips or even a bipolar instrument. Perhaps one of the most technically important moves during left adrenal surgery is the division of the left lateral attachments of the spleen to allow the spleen to flip toward the right part of the abdomen, frequently allowing visualization of the stomach. With the patient in the lateral position, the spleen, pancreas, and the left viscera are kept self-retracted by their own weight. Hugging Gerota's fascia during the mediovisceral rotation assures avoidance of injury to the colon, pancreas, spleen, or splenic vessels.

Postoperative Complications and Patient Management

General postoperative surgical management guidelines apply to postadrenalectomy and partial adrenalectomy patients regardless of the approach. These recommendations include early ambulation, subcutaneous heparin, and sequential compression devicess for deep vein thrombosis prophylaxis, the use of an incentive spirometer, and adequate pain control. Postoperative vitals and labs including blood counts and electrolytes should be carefully monitored. Most recommend ICU or close level monitoring after adrenal surgery for functional masses to allow for immediate recognition of the addisonian crisis and the opportunity for rapid intervention if needed.[53] While usual surgical complications, such as bleeding, infection, damage to adjacent structures and organs, or pneumothorax can be seen with all types of adrenal tumors, a specific recognition of disease-specific complications is paramount (Boxes 39.3, 39.4).

HYPERALDOSTERONISM

Postoperative management for patients with APA entails monitoring electrolytes and achieving normokalemia with potassium chloride supplements and blood pressure

Box 39.3 Complications of Complete Adrenalectomy

Lack of endogenous steroid production
Steroid dependence, with dosing adjustment issues
  Mood changes, diarrhea, abdominal distention, nausea, dyspepsia, increased appetite, peptic ulcers, adrenal suppression, candidiasis, hirsutism, increased intraocular pressure, immunosuppression, hypertension, edema, hypokalemia
Increased fatigue
Decreased resistance to stress and infection
Increased risk of osteoporosis
Uncontrolled weight gain

(Modified from Kaye DR, Storey BB, Pacak K, Pinto PA, Linehan WM, Bratslavsky G. Partial adrenalectomy: underused first line therapy for small adrenal tumors. J Urol. 2010;184(1):18-25.)

Box 39.4 Postoperative Complications of Adrenal Surgery

Primary Aldosteronism

Hypokalemia: secondary to continued potassium loss immediately postoperatively
Hyperkalemia: secondary to failure of contralateral adrenal gland to secrete aldosterone

Cushing's Syndrome

Inadequate steroid replacement leading to hypocortisolism
Fracture secondary to osteoporosis
Hyperglycemia
Poor wound healing
Increased risk of infection

Pheochromocytoma

Hypotension secondary to α-adrenergic blockade after tumor removal

Generic Complications

Hemorrhage
  Inferior vena cava
  Adrenal arteries
Pneumothorax
Pancreatitis
Pneumonia
Hiccups

(From Vaughan ED Jr. Complications of adrenal surgery In: Taneja SS, RM Ehrlich RM, Smith RB, eds. Complications of Urologic Surgery. 3rd ed. Philadelphia; WB Saunders; 2000:362-9.)

monitoring for risk of hypotension. Antihypertensive medications can be weaned based on blood pressure monitoring, and mineralocorticoid receptor antagonists can be stopped. One rare complication to be aware of is the postoperative paradoxical effect of salt wasting and hyperkalemia as a result of the contralateral adrenal efforts to compensate for the hyperfunctioning gland.[54]

PHEOCHROMOCYTOMA

Patients who undergo adrenalectomy or partial adrenalectomy for pheochromocytoma should receive postoperative monitoring in the surgical intensive care unit for blood pressure control and occasionally hypoglycemia. Side effects of the surgery will largely depend on the quality of preoperative blockade and occur due to the rapid withdrawal of excess catecholamines.[55] Volume status is carefully monitored and IV fluids are slowly decreased postoperatively to allow for intravascular volume to be adequately equilibrated. The preoperative blockade is stopped immediately after the surgery.

CUSHING'S SYNDROME

Negative feedback from a hyperfunctioning adrenal gland with overproduction of cortisol inhibits the production of adrenocorticotropic hormone (ACTH) by means of inhibition of the hypothalamic pituitary axis (HPA). This in turn may cause the contralateral adrenal gland to atrophy. Therefore glucocorticoid must not only be administered preoperatively but be adequately replaced postoperatively to compensate for the lack of contralateral adrenal gland production. Initially, it is recommended to administer high stress doses of the steroid medications with tapering thereafter. The process of adequate replacement must continue until the HPA axis and contralateral adrenal gland are functioning in synchrony, which sometimes may take up to several months.[20] The cosyntropin test can measure the response of the adrenal gland to ACTH stimulation and be a good indicator for the ability to taper the steroids off.[56] In the case of bilateral adrenalectomy for Cushing's disease, patients may require lifelong corticosteroid replacement. In the postoperative period these patients should be monitored closely due to their propensity of wound healing complications and risk of infections. Side effects similar to Cushing's disease may be seen with long-term steroid replacement and include osteoporosis resulting in pathologic fractures, as well as obesity, growth retardation in children, diabetes, and ophthalmologic problems.[57,58]

Most Important Postoperative Considerations and Tips

1. Strongly consider ICU or step-down after any adrenal surgery because of the potential for postoperative hypotension and the need for frequent monitoring of vital signs.
2. In case the patient exhibits signs of hypotension, in addition to IV boluses of fluid and routine postoperative labs, the administration of steroid bolus (100 mg hydrocortisone) should be performed. The importance of communication with house staff or physicians caring for the patient in the perioperative period cannot be overemphasized.
3. In cases of long-standing hypercorticosolemia in patients undergoing a rapid steroid taper or any patient undergoing surgery for any pathology on a solitary adrenal gland a cortisol stimulation test should be strongly considered to evaluate for an adrenal response to adrenocorticotropic hormone (ACTH) stimulation.
4. When discharging patients that underwent surgery after prolonged hypercorticosolemia or in the case of a solitary adrenal gland a prescription for hydrocortisone 20 mg should be given with patients being instructed to carry this medication with them at all times and immediately take 20–60 mg orally should they feel weakness or any suspicion of low blood pressure or symptoms consistent with addisonian crisis at the time of any illnesses, trauma, or potentially other surgeries. These patients need to communicate

their potential risk for the addisonian crisis with every health-care provider they encounter in the future and remain vigilant about their condition even in the case of relatively minor stress such as a simple cold or infection.

Key Points of Adrenal Surgery: Prevention of Complications

1. Know what you are dealing with (complete the metabolic workup).
2. Do not forget to get a washout evaluation in tumors with greater than 10 HU on noncontrasted computerized tomography.
3. Suspect metastasis in every adrenal tumor in a patient with a history of other cancer, but do not forget that primary adrenal tumors can still form in cancer patients (complete the metabolic evaluation).
4. Do not forget to block patients for pheochromocytoma (start with alpha blockade first).
5. Obtain adequate IV access for all adrenal surgeries.
6. Do not forget to give stress dose steroids for those with cortisol-secreting tumors, and taper off carefully postoperatively.
7. Watch for a short right adrenal vein originating posterolaterally from the inferior vena cava during right-sided adrenal surgery.
8. Strongly consider ICU postoperatively and recognize adrenal crisis in postoperative patients who become hypotensive and do not respond to IV fluid resuscitation (use stress dose steroids).
9. Consider adrenal preservation even in those with a normal contralateral adrenal gland (partial adrenalectomy).

References

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Chapter 39 Questions

Case Study 1

A 28-year-old female with a history of high blood pressure presents to the clinic with palpitations, anxiety, headachec and facial flushing. Her recorded blood pressures are generally around 160/90. Routine blood tests are normal.

1. What is the best initial screening test to evaluate this patient's condition?
   a. Adrenal venous sampling
   b. 24-hour urine catecholamines
   c. Dexamethasone suppression test (DST)
   d. Clonidine suppression test
   e. Plasma free metanephrines

2. What is the test with the highest specificity for this patient's condition if the above test is positive?
   a. Plasma free metanephrines
   b. 24-hour urinary catecholamines
   c. MIBG scan
   d. MRI abdomen and pelvis
   e. Adrenal venous sampling

3. Which of the following will not significantly affect plasma levels of metanephrines during the screening of pheochromocytoma?
   a. Tylenol
   b. Motrin
   c. Caffeine
   d. Tricyclic antidepressants
   e. None of the above

4. The above confirmatory test is positive, and the patient has been scheduled for surgery. Which medication(s) below should be started preoperatively?
   a. Alpha-blockers
   b. Beta-blockers
   c. Metyrosine
   d. Beta-blockers followed by alpha blockade
   e. Beta-blockers with metyrosine

5. After the mass is removed, the patient's blood pressure drops to 80/40 intraoperatively. What is the best initial step in management?
   a. Aggressive hydration
   b. Alpha agonist
   c. Beta agonist
   d. Alpha and beta agonists
   e. Vasopressor support

Case Study 2

A 43-year-old male with a history of depression presents with increased upper body obesity, rounded face, and increased fat around the neck. He is concerned because he recently noticed these changes when looking at an old picture of himself in a photo album.

1. Which of the following tests is NOT indicated for initial screening of his disease?
   a. 1-mg dexamethasone suppression test
   b. 8-mg dexamethasone suppression test
   c. 24-hour urinary free cortisol level
   d. Late-night salivary cortisol
   e. a and c

2. The patient is eventually diagnosed with a cortisol producing adenoma that measures 2.3 cm, and he is taken to the operating room for a left robotic-assisted partial adrenalectomy. During the surgery, the anesthesia team reports challenges with ventilating the patient and you notice bellowing of the left diaphragm with limited visualization of the operating field. Your next step in management is:
   a. Changing the ventilator settings to pressure control mode
   b. Identify diaphragmatic injury, evacuate the air from the chest using laparoscopic suctioning, and repair the diaphragm
   c. Convert robotic procedure to open immediately
   d. Reposition the patient, place a chest tube, and complete the procedure in a minimally invasive fashion
   e. Have surgical team place a chest tube without repositioning the patient

3. Two weeks postoperatively the patient presents to the emergency room with nausea, abdominal pain, and fever. CT scan from the emergency room reveals a fluid collection that after drainage by interventional radiology appears milky and high in amylase. What is the next step in management?
   a. Instillation of a sclerosing agent into the drainage tract
   b. Bowel rest, TPN, and continue drainage
   c. Emergent exploration of suspected pancreatic injury
   d. Upper endoscopy and endoscopic retrograde cholangiopancreatography (ERCP)
   e. Medical admission for IV antibiotics

4. Ten years postoperatively the patient is found to have a 4.8-cm right adrenal mass that does not fit the characteristics of an adenoma on CT adrenal mass protocol and is also biochemically inactive. Luckily, there is an excellent left adrenal remnant that appears normal and you choose to proceed with a right adrenalectomy. As you dissect along the IVC, you expect to find:
   a. Short right adrenal vein posterolaterally
   b. Short right adrenal vein anterolaterally
   c. Long right adrenal vein posterolaterally
   d. Long right adrenal vein anterolaterally
   e. None of the above

Case Study 3

A 55-year-old man presents with a 2.3-cm incidental finding of adrenal mass on noncontrast enhanced CT of the abdomen and pelvis. The patient is normotensive and asymptomatic. The mass measures 5 Hounsfield units on noncontrasted imaging.

1. What is the next step in management?
   a. CT adrenal mass protocol
   b. Metabolic workup
   c. MRI abdomen/pelvis with contrast
   d. No further workup is necessary
   e. a and b

Case Study 4

A 63-year-old female presents with a 4.3-cm adrenal mass. She is asymptomatic. Biochemical workup is negative. CT adrenal mass protocol is done and shows an absolute washout of 20%.

1. What is the next best step in management of this patient's findings?
   a. T2-weighted MRI of the abdomen
   b. Metaiodobenzylguanidine scan
   c. Adrenalectomy
   d. Repeat biochemical workup
   e. Observation with repeat imaging in 6–12 months

Case Study 5

A 75-year-old male with a history of kidney cancer 2 years previously is found to have a 2.1-cm adrenal mass on surveillance CT scan.

1. The next step in management is:
   a. Adrenal mass biopsy
   b. Adrenal mass resection
   c. Metabolic workup
   d. Begin systemic therapy for kidney cancer
   e. Observation with repeat imaging in 6–12 months

2. After making the diagnosis of Conn's tumor, prior to taking a patient to the operating room, one must:
   a. Operate only on the site with the visible tumor
   b. Start the patient on alpha-blocker therapy preoperatively
   c. Salt load testing
   d. Perform adrenal vein sampling to lateralize the origin of the increased aldosterone secretion
   e. a and c

Answers

CASE STUDY 1

1. **e.** Plasma free metanephrines are the most sensitive initial screening test for pheochromocytoma.
2. **b.** The highest specificity or pheochromocytoma is 24-hour urine catecholamines.
3. **b.** NSAIDs will not significantly affect plasma levels of metanephrines.
4. **a.** Prior to surgery, first start alpha blockade followed by beta blockade.
5. **a.** Initial management for a drop in blood pressure that can occur after removal of a pheochromocytoma is aggressive fluid resuscitation.

CASE STUDY 2

1. **b.** Given the clinical history, initial testing can be with a 1-mg dexamethasone suppression test, a 24-hour urinary free cortisol level, or a late night salivary cortisol test.
2. **b.** Laparoscopic repair of the diaphragm after evacuating the air from the chest cavity is achievable with suction and closure of the defect.
3. **b.** The treatment strategy for a pancreatic leak includes bowel rest, TPN, and continued drainage of the collection.
4. **a.** The correct anatomy off of the IVC is a short posterolateral right adrenal vein.

CASE STUDY 3

1. **b.** Due to the HU being <10, further imaging is not indicated. But a metabolic workup should be completed.

CASE STUDY 4

1. **c.** Given the size >4cm, strong consideration should be given for removal of the mass which has risk for an adrenal carcinoma.

CASE STUDY 5

1. **c.** Metabolic evaluation is always recommended for adrenal masses.
2. **d.** It is important to determine laterality of these tumors prior to surgical intervention.

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40 Complications of Lymphadenectomy

DMITRY VOLKIN and WILLIAM C. HUANG

CHAPTER OUTLINE

Retroperitoneal Lymph Node Dissection
Complications of Retroperitoneal Lymph Node Dissection
Failure of Ejaculation
Lymphocele
Chylous Ascites
Vascular Complications
Venous Complications
Venous Anomalies
Arterial Complications
Gastrointestinal Complications
Complications of Pelvic Lymph Node Dissection
Considerations in Radical Prostatectomy
Considerations in Radical Cystectomy
Nerve Injury
Obturator
Genitofemoral
Femoral
Management of Pelvic Nerve Injuries
Lymphocele
Thromboembolic Events
Vascular Injury
Complications of Inguinal Lymph Node Dissection
Cutaneous Complications
Lymphatic Complications
Deep Vein Thrombosis
Chapter 40 Questions and Answers

KEY POINTS

1. Lymphadenectomy is a critical component of surgery for many urologic malignancies, providing both therapeutic and diagnostic benefit.
2. A comprehensive knowledge of retroperitoneal and pelvic anatomy is paramount in avoiding serious complications as a result of lymphadenectomy.
3. By providing improved visualization and operator dexterity, minimally invasive surgery may aid in decreasing complication rates in certain clinical scenarios.

Lymphadenectomy is a procedure in which the lymph nodes draining an organ or tumor are surgically removed. This is a critical step in the management of urologic malignancies and has two primary goals. First, it provides diagnostic information that can be used to appropriately stage patients, guiding subsequent treatment. Second, it provides the therapeutic benefit of removing cancerous tissue that is potentially harbored within these lymph nodes.

Much of the morbidity of lymphadenectomy is related to the extent of anatomic dissection required to remove an adequate number of nodes. A significant amount of research is being directed at the development of tests or imaging techniques that can reliably identify cancerous lymph nodes prior to surgery, so only affected nodes may be targeted. Although many important strides have been made, the negative predictive value of current techniques is not yet sufficient to displace the current practice of surgical lymph node removal.

This chapter will focus on anatomic considerations and surgical techniques to avoid the often debilitating complications of lymphadenectomy. We will discuss the incidence of common complications and their management when they occur. We make an effort to comment on the integration of minimally invasive surgery as it applies to the morbidity of lymphadenectomy.

Retroperitoneal Lymph Node Dissection

Retroperitoneal lymph node dissection (RPLND) has played an integral part in the management of testicular cancer since Hinman published the first report of a curative dissection in 1914. Over the past century, the technique has evolved and has been substantially refined. Despite advances in imaging and systemic treatment options, RPLND continues to be utilized in the management of patients with both localized and metastatic germ cell tumors.

Historically, some patients have likely been deterred from choosing RPLND as a primary treatment option despite its excellent success rate of nearly 100% and 95% in stage I and II nonseminomatous germ cell tumors (NSGCT), respectively.[1,2] This is likely due to a combination of factors. First, RPLND is a major abdominal operation with significant associated morbidity and typical hospital course of 7 days or longer.

Second, it is an infrequently performed operation by urologists outside of major academic or cancer centers. However, with the development of the less morbid robotic RPLND in recent years, this procedure will likely see increased use as long as oncologic outcomes prove to be noninferior.

While RPLND for NSGCT will be the basis of our discussion in this chapter, it is employed in a number of clinical scenarios beyond testicular cancer. It is commonly performed at the time of nephrectomy for renal cell carcinoma and has been shown to have benefit in patients undergoing nephroureterectomy for upper tract urothelial carcinoma. The extent of dissection in these last two clinical scenarios is not well defined.[3,4]

COMPLICATIONS OF RETROPERITONEAL LYMPH NODE DISSECTION

It should be noted that complications of RPLND vary based upon the setting in which it is performed. RPLND performed after chemotherapy can be significantly more challenging due to the intense desmoplastic reaction typically present in the retroperitoneum. Not surprisingly, complication rates in these patients are significantly higher than after primary RPLND.[5] Minimally invasive pcRPLND can be even more challenging still. The conversion rate in one early study was as high as 78%, but as experience with this technique has grown, open conversion has become much less common.[6–9] In one case series published in 2013 from an experienced group, only one out of 100 patients was converted to open surgery.[10]

Failure of Ejaculation

Given the young age group in which RPLND is typically performed, preservation of fertility is an important consideration. The process of emission during male orgasm is a complex reflex coordinated by the sympathetic nervous system; the nerves involved in this reflex are at risk during surgical dissection. Thankfully, damage to the sympathetic innervation on only one side will typically not result in loss of antegrade ejaculation.[11] This physiologic principle is the basis for the evolution of the RPLND technique over the last few decades.

Knowledge of the neural anatomy of the retroperitoneum is critical in order to prevent injury. The sympathetic chains run parallel to the great vessels in the space between the psoas muscle and spinal column. The right sympathetic chain is posterior to the inferior vena cava (IVC), while the left sympathetic chain is posterolateral to the aorta. At the level of L1 and L2, the sympathetic chain gives off postganglionic sympathetic nerve fibers, also known as lumbar splanchnic nerves, which form the intermesenteric plexus over the anterior surface of the aorta (Fig. 40.1). The aortic plexus is composed of four bilaterally symmetric ganglia: the right and left spermatic ganglia, the inferior mesenteric ganglion on the left, and the prehypogastric ganglion on the right (Fig. 40.2).[12] The sympathetic nerves from the aortic plexus continue into the hypogastric plexus, typically located between the two common iliac arteries, to eventually innervate the pelvic viscera.

Damage to any of these neuronal structures during the surgical dissection may result in failure of antegrade ejaculation postoperatively. To prevent injury, great care must be taken when controlling the lumbar vessels, which are intimately involved with the sympathetic chain. Also, postganglionic sympathetic nerve fibers on the left side must be isolated with a vessel loop prior to performing "split and roll" over the aorta. This is in contrast to the IVC, where significant nerve tissue is not encountered on the anterior surface.

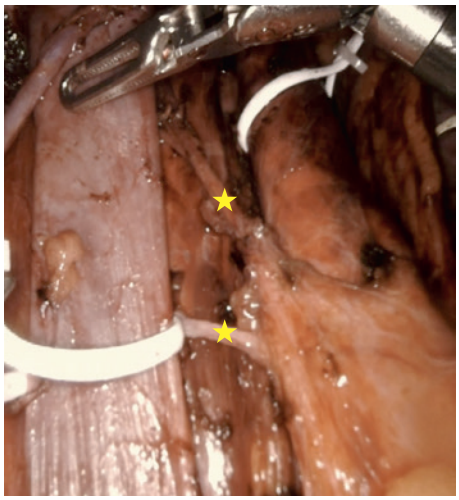


Figure 40.1 Inferior vena cava and aorta are skeletonized and encircled with vessel loops during robotic RPLND. Post-ganglionic sympathetic nerve fibers running over the aorta are spared.

While failure of antegrade ejaculation was a consistent outcome during early, wide boundary bilateral RPLND, more recent series report preservation in 85–100% of patients, and 91% in the largest series of robotic RPLND to date.[9,13–15] This is partly from adoption of nerve sparing techniques, in which the sympathetic chain, post-ganglionic fibers, and hypogastric plexus are identified and meticulously dissected. It is also a result of instituting modified templates for RPLND, which aim to resect all potential disease and landing zones on the ipsilateral side, while limiting dissection of the contralateral side, especially below the inferior mesenteric artery. The particular template used should never compromise cancer control to preserve antegrade ejaculation.

Patients should be asked about their plans for having children and should be offered sperm banking prior to surgery. If there is failure of antegrade ejaculation postoperatively, administration of pseudoephedrine may be useful in select patients with true retrograde ejaculation (as compared with failure of emission).[16] In those with failure of emission, electroejaculation has been shown to successfully produce motile sperm in 87% of men.[17] If no viable sperm can be obtained in this fashion, testicular sperm extraction is typically the last resort.

Lymphocele

As in the rest of the body, retroperitoneal lymphatics run in close association with the vasculature. The lymph from the common iliac nodes passes to the right and left lumbar lymph nodes, which lie on either side of the IVC and aorta. The lymph from the descending colon, kidneys, ureters, and testes also drain into these nodes. The efferent vessels from these nodes then form the lumbar lymphatic trunks, which then join with the intestinal lymphatic trunks to

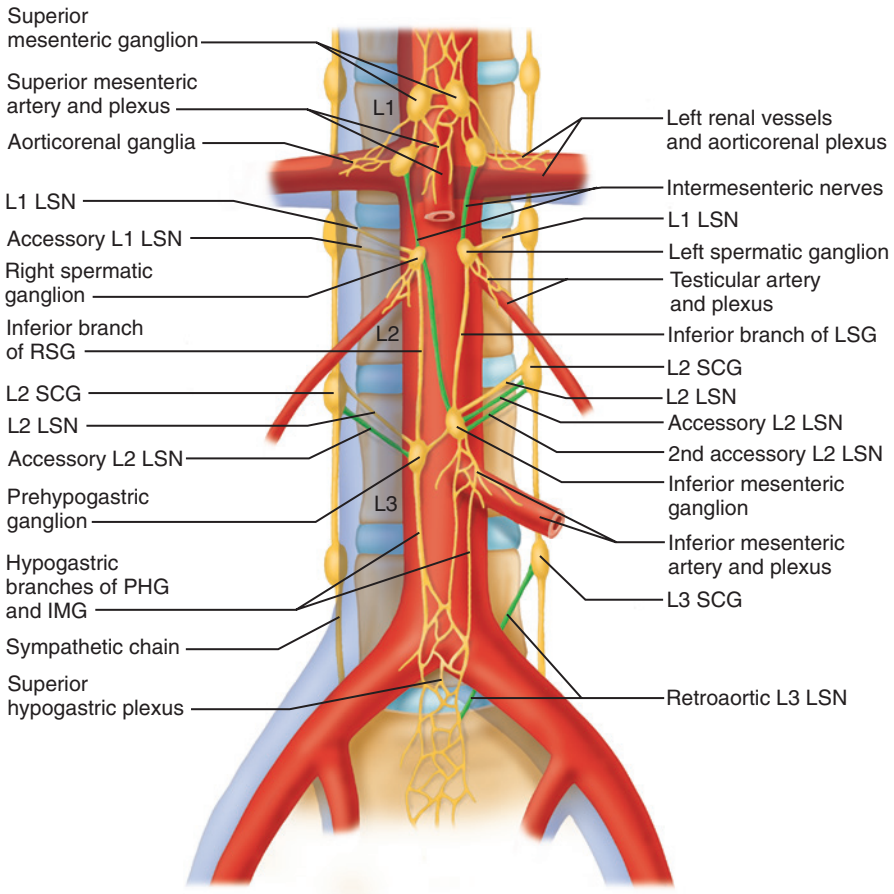


Figure 40.2 Sympathetic ganglia of the aortic plexus. IMG, inferior mesenteric ganglion; LSG, left spermatic ganglion; LSN, lumbar splanchnic nerve; PHG, prehypogastric ganglion; RSG, right spermatic ganglion; SCG, sympathetic chain ganglion. (From Beveridge TS, et al. Anatomy of the nerves and ganglia of the aortic plexus in males. J. Anat. 2015; 226(1):93-103.)

form the proximal thoracic duct. The beginning of the thoracic duct will variably form a saccular dilatation known as the cisterna chyli, found anterior to bodies of the L2 or L1 vertebra between the right crus of the diaphragm and the aorta. The size and shape of this structure varies considerably between patients, if present at all. Often, there will only be a plexus of lymphatic trunks coalescing into the thoracic duct.

Controlling the retroperitoneal lymphatic vessels at the time of dissection is the most important technique to prevent lymphatic complications, including lymphoceles, which are described below, and chylous ascites, which is described in the following section. In addition to the lymphatic channels mentioned above, special attention should be paid to ligating the numerous lymphatic channels when reflecting the duodenum and pancreas off the left renal vein underneath. The same is true when mobilizing the tail of the pancreas near the ligament of Treitz.

A lymphocele is a collection of lymphatic fluid that accumulates in the retroperitoneum after damage to any of the lymphatic vessels during RPLND. Small lymphoceles are common after RPLND, are typically asymptomatic, and require no treatment. However, lymphoceles can become clinically significant if they are large, causing abdominal fullness and discomfort, if they compress other structures in the retroperitoneum such as the ureter or the inferior vena cava, or if they become infected.

If there is a clinical suspicion for postoperative lymphocele, a CT with contrast, or other cross-sectional imaging, should be obtained. Typically, a lymphocele will be identified as a thin-walled cystic structure in the retroperitoneum with simple fluid within. If there is significant loculation, enhancement of the wall, or air within the structure, there should be a high concern for abscess or infected lymphocele, especially in the presence of fevers. These should be treated with percutaneous drainage and antibiotics. The management of noninfected lymphoceles will be discussed in the pelvic lymphadenectomy section later in this chapter.

Chylous Ascites

Intraoperative injury to the larger lymphatic structures within the retroperitoneum, namely the major lymphatic trunks or cisterna chyli, can result in continuous lymphatic leakage that outpaces reabsorption. This fluid will accumulate within the abdomen and cause increasing abdominal distention and patient discomfort. This is known as chylous ascites. In some cases, this can also lead to dyspnea from increased intraabdominal pressure on the diaphragm or from lymphatic leakage into the thorax itself. The latter is usually a result of injury to the thoracic duct during retrocural dissection.[18]

Chylous ascites can occur following RPLND for any indication, including renal cell carcinoma (Fig. 40.3). In GCTs, it is a fairly rare complication but rates vary based on the

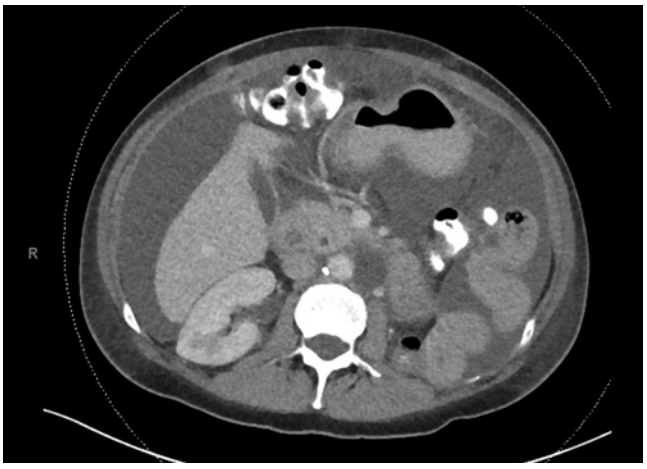


Figure 40.3 Chylous ascites 2 weeks after left nephrectomy and retroperitoneal lymph node dissection for advanced renal cell carcinoma.

setting of RPLND. In primary RPLND, the rate is approximately 2%, compared with 2–7% in pcRPLND.[5,19,20] In laparoscopic RPLND rates of chlyous ascites range from 1% to 7%.[10,21,22] Patients that require resection of the IVC during pcRPLND are at increased risk for chylous ascites, presumably from increased peripheral venous pressure that is transmitted to the lymphatic system. In a series of 603 patients undergoing pcRPLND, half of all patients with chylous ascites had resection of the IVC at the time of surgery.[5]

If chylous ascites is suspected after RPLND, the patient should be percutaneously drained and the fluid sent for analysis. High lymphocyte, protein, and triglyceride levels confirm the diagnosis. Since the majority of chyle is made up of chlyomicrons converted from dietary fat, the first step in management of these patients is to modify their diet to one high in protein and low in fat. The dietary fat should be primarily composed of medium chain triglycerides, which are transported directly to the portal circulation. This type of diet limits the flow of chyle into the lymphatics, promoting spontaneous closure of the injured vessels. Although time to resolution is variable, it typically takes a number of weeks or longer to completely resolve with conservative measures. This may result in repeated paracentesis while awaiting resolution of the ascites. The decision to leave an indwelling drain is controversial. Proponents of indwelling drains cite the ability to track the output and prevent repeated paracentesis, while opponents worry about the increased rate of infection and peritonitis.

If the chylous ascites does not resolve with a fat restricted diet, the second-line option is complete bowel rest with total parenteral nutrition. Evans et al. reported resolution of chylous ascites in 77% of patients with parenteral nutrition and paracentesis with or without abdominal drain placement.[20] A number of studies also support the use of octreotide, a somatostatin analog, as another method to attenuate the flow of intestinal lymph. This should be started at a dose of 100 µg subcutaneously three times a day, but can be titrated up to 12 mg via continuous infusion.[23] Octreotide has proven to be useful both on its own and in conjunction with total parenteral nutrition and medium-chain triglyceride diet.[24–27]



Figure 40.4 Lymphangiography with poppy seed oil in a man with refractory chylous ascites following retroperitoneal lymph node dissection (RPLND) for nonseminomatous germ cell tumor.

If these conservative measures do not resolve the ascites, more aggressive approaches may be necessary. Bipedal lymphangiography along with injection of iodinated poppy seed oil has been shown to resolve chylous leaks, especially those classified as minor (seen only on CT after lymphangiography, not on radiography) (Fig. 40.4).[28,29] The amount of leakage per day with a drain in place is predictive of resolution with lymphangiography. In patients with leakage less than 200 mL/day after conservative measures, lymphangiography was successful in 97% of patients in one study.[30] If lymphangiography itself does not resolve the leak, it can still be a useful adjunct prior to surgery to ligate the leaking vessels.[31] Other approaches to refractory chylous ascites described in the literature include local radiation, sclerotherapy, and peritovenous shunting. However, the latter method is associated with significant morbidity and should be reserved for cases in which conservative measures fail.[20,32–35]

Vascular Complications

The most feared and potentially catastrophic complication of RPLND is vascular injury. Specific management of vascular injury is discussed in detail in Chapter 10, but here we discuss injuries specific to RPLND. While rare in the primary setting for germ cell tumors, injury to major vessels is a significant risk in patients undergoing pcRPLND or in patients undergoing nephrectomy with significant retroperitoneal adenopathy.

In the pcRPLND setting, the factors responsible for this increased risk are twofold. First, there is a dense

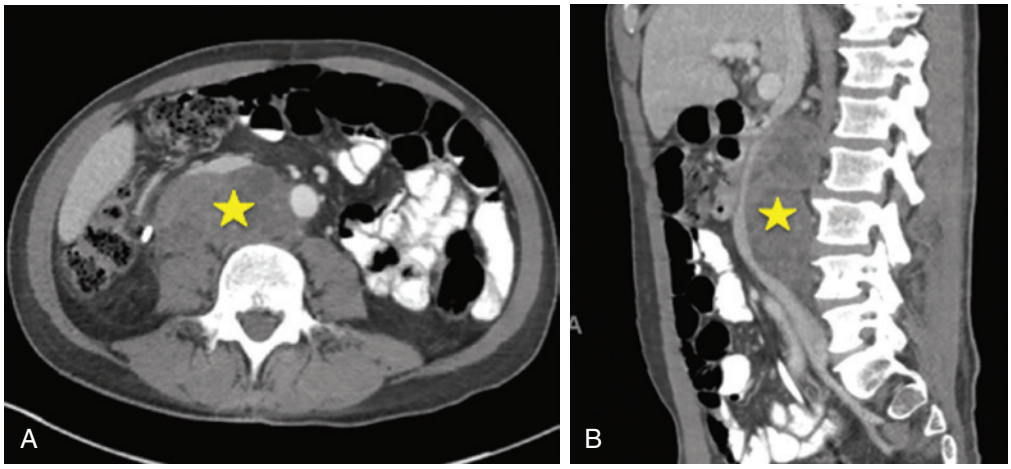


Figure 40.5 Large mass posterior to inferior vena cava (IVC) (star) in axial (A) and sagittal (B) views. The mass both compresses the vein and displaces it anteriorly.

inflammatory reaction within the retroperitoneum after chemotherapy in these men, which makes dissection along anatomic fascial planes much more difficult. Also, pcRPLND is more likely to be performed in men with larger, advanced tumors, some of which can invade adjacent organs or vascular structures. In a nationwide study of patients undergoing RPLND between 2007 and 2012, the rate of adjunctive procedures, such as nephrectomy or vascular reconstruction, was 19% in the post chemotherapy setting, compared to 1% during primary RPLND.[36]

When the need for pcRPLND arises, a thorough evaluation of the patient and all preoperative imaging is paramount. Clues to vascular invasion present on physical exam include lower extremity edema and well-developed abdominal collateral circulation. A large bulky tumor that abuts major vascular structures on CT scan, especially on the right side, suggests that vascular reconstruction may be necessary (Fig. 40.5). While not standard of care, MRI may be useful to further delineate vascular anatomy and the likelihood that the retroperitoneal mass invades adjacent structures.[37]

In all cases, the surgeon performing pcRPLND must be keenly aware of variations in vascular anatomy and must be comfortable with vascular control techniques. Given the complexity of the operation, pcRPLND should be performed in referral centers by experienced surgeons whenever possible. It is also prudent to have a vascular surgeon available to assist with major reconstruction if it becomes necessary.

Venous Complications

Venous hemorrhage can be a significant problem in pcRPLND, especially when dealing with bulky right-sided masses that are encroaching on the IVC and its tributaries. Although injury to vessels should be carefully avoided, transection of most major veins, including the IVC, can usually be overcome without reconstruction, thanks to the rich supply of collaterals in the abdomen and pelvis. The exceptions to this rule are the superior mesenteric, portal, and right renal veins. Damage to these vessels almost invariably requires reconstruction.[38]

One of the most common areas of difficulty is the ligation of the fragile lumbar veins draining into the IVC. While classically described as entering the IVC at each lumbar level, there can be significant variation in the number and location of lumbar veins. In one study from Indiana University, the lumbar venous anatomy was examined in 102 consecutive RPLNDs.[39] The authors noted that the number of infrarenal lumbar veins may vary from 0–4 on the right and 1–4 on the left. Also, a significant number of patients had two or more lumbar veins that combined into a common trunk before draining into the IVC, and 43% of patients had a lumbar vein that entered the left renal vein.

The lumbar veins can easily be avulsed by excessive traction or sheared by excessive force during ligation. To maximize exposure, the IVC should gently be retracted while the lumbar vessels are controlled by suture ligature or hemoclips. If a lumbar vessel is avulsed, it will often retract into the posterior wall musculature or vertebral foramen, resulting in bleeding that may be difficult to control. In these cases, the surgeon may use a sponge stick to compress the psoas muscle against the vertebral body at that level, thereby compressing the lumbar vein and ascending lumbar vein that runs under it. If the bleeding vessel cannot be controlled directly, the psoas muscle may be sutured to the paraspinal ligament underneath. This will usually control the bleeding and preclude the need for retro-psoas exploration.

Unlike the right renal vein, the left renal vein has a longer course and generally has multiple tributaries. Dissection of a large para-aortic mass can obscure the points of drainage of the gonadal, adrenal, or lumbar veins, resulting in injury to the left renal vein. Small lacerations can be repaired with nonabsorbable suture, usually 5-0. If the vessel is transected, avulsed, or there is a large laceration, the need for reconstruction is not clearly indicated.

Much of the data regarding left renal vein ligation come from the vascular surgery literature. Mehta et al.[40] found that postoperative renal functional outcomes were similar between 48 patients undergoing abdominal aortic aneurysm (AAA) repair and left renal vein ligation without reconstruction, and 213 patients with intact renal veins. Stability of renal function after ligation of the left renal vein has been confirmed to at least 1 year after surgery.[41] However, other authors argue that reconstruction of the left renal vein should be attempted, if possible, in order to better preserve preoperative renal function.[42]

Although the above studies are useful to understand the general morbidity of left renal vein ligation, the hemodynamics and drainage of the left kidney in the context of retroperitoneal malignancy are different. In cases where the retroperitoneal mass chronically occludes the left renal vein, collaterals are often well developed, and ligation is likely to be well tolerated. That being said, patients with poor preoperative renal function and those with a solitary left kidney would probably benefit from repair. Similarly, if collateral vessels draining the left kidney are sacrificed during the course of dissection, the renal vein should be repaired. Of note, ligation of the right renal vein without reconstruction will almost invariably lead to loss of the right kidney.

In both renal cell carcinoma (RCC) and GCTs, a small, but not insignificant portion of cases may involve a mass that encases the IVC, invades the wall, or has tumor thrombus extending into its lumen. Also, in the setting of pcRPLND, the severe desmoplastic reaction after chemotherapy may make dissection of the mass from the wall of the IVC impossible. In all of these cases, en bloc removal of a portion of the IVC may be necessary. In a large study of 955 patients undergoing pcRPLND, Beck and Lalka reported 6.8% required infrarenal IVC resection, with almost one-third of those resected harboring tumor within the cava.[43]

Thanks to abundant collateral venous flow, the infrarenal IVC may be sacrificed in order to gain a complete resection and improve survival. However, patients undergoing caval resection can have significant acute and chronic disability. The decreased venous return causes a rise in peripheral venous pressure, leading to increased secretion of lymphatic fluid and risk of postoperative chylous ascites. The increased peripheral venous pressure is also responsible for edema and chronic ulceration of the lower extremities, which can be extremely difficult to treat. Lastly, venous thromboembolism may occur as a result of increased pressures and turbulent flow.

The morbidity of IVC resection is closely related to the chronicity and extent of IVC occlusion. In the case of acute occlusion, where collateral vessels have not had a chance to form, most patients will suffer significant disability. Donaldson et al. discussed long-term outcomes of patients undergoing acute IVC ligation to prevent pulmonary embolism and noted that 61% of their cohort had some degree of leg swelling postoperatively. Stasis ulcers or edema poorly responsive to compression stockings was found in 30% of the same group.[44]

In contrast, there appears to be only minor changes in venous hemodynamics after resection of an occluded IVC.[45] Many authors have demonstrated that transection of the IVC in patients with tumor involvement does not result in significant long-term morbidity in most patients. Spitz et al. reported lower extremity symptoms in four of 11 patients 6 months after IVC resection during RPLND, but these were generally mild.[46] In the study by Beck and Lalka mentioned earlier, of the 20 patients for whom disability scores could be calculated, only two had moderate disability, and one had severe disability at long-term follow-up.[43] In their cohort, Blute et al. reported that no patients had disability that precluded them from working and 70% of patients did not need compression stockings for daily activity of up to 8 hours. Furthermore, their study suggests that venous collateralization continues to occur after IVC resection, as many patients had postoperative improvement of their preoperative disability scores.[47] This has been confirmed in other reports.[48]

Given the available evidence, IVC reconstruction is not necessary in patients with chronic complete, or near complete, occlusion. Preoperative imaging with MR angiography can help to define the extent of tumor involvement and the degree of IVC occlusion, as well as the degree of collateral vessel compensation.[49] If the IVC will not be reconstructed, it is critical to spare these collateral vessels during the dissection, as they are responsible for collateral drainage into the azygous and hemi-azygous system when the IVC is ligated.

In cases where the IVC is only partially occluded, a number of options are available. If feasible, a portion of the IVC can be resected and repaired primarily. The accepted belief is that the IVC may be narrowed by up to 50% of its original diameter without resulting in significant consequence. Alternatively, a patch graft may be used for larger repairs. These types of scenarios have been managed successfully via a minimally invasive approach, with low overall morbidity.[50]

If the IVC must be transected completely and reconstruction is indicated, a biologic or synthetic graft can be used. Reconstruction with a polytetrafluoroethylene (PTFE) graft is most common and has been shown to prevent lower extremity complications in nearly all patients.[51,52] However, patients undergoing grafting have a higher rate of postoperative venous thromboembolic (VTE) events and the graft itself can thrombose.[53] Also, grafting adds significant operative time to an already lengthy procedure. A further consideration is that patients undergoing IVC resection have advanced disease, and many of them may require chemotherapy postoperatively, rendering them immunocompromised. This results in at least a theoretical increased risk of graft infection.

Venous Anomalies

Surgeons performing RPLND should be aware of possible variations in retroperitoneal venous anatomy. These variations can further complicate an already difficult dissection, especially if not anticipated or detected on preoperative imaging. The most common anatomic abnormalities are a double vena cava, a left-sided IVC, a circumaortic left renal vein (circumaortic renal collar), or a retroaortic left renal vein. Complete situs inversus is also possible, but very rare.

A double vena cava occurs in as many as 2–3% of all people, based on cadaveric studies. The left-sided trunk typically joins with the left renal vein and crosses the midline, either posterior or anterior to the aorta, to drain into the right-sided trunk, which then ascends into the thorax normally. Typically, the right-sided trunk is dominant, but this is variable.[54–56]

Transposition of the vena cava or left-sided cava is a rare anomaly, occurring in approximately 0.5% of patients. If present, the vena cava will ascend on the left side until the level of the renal vessels, where it will typically cross the midline anterior to the aorta and caudal to the superior mesenteric artery. It then normally ascends into the thorax. The transposed vena cava may also cross posterior to the aorta, but this is less common.[56]

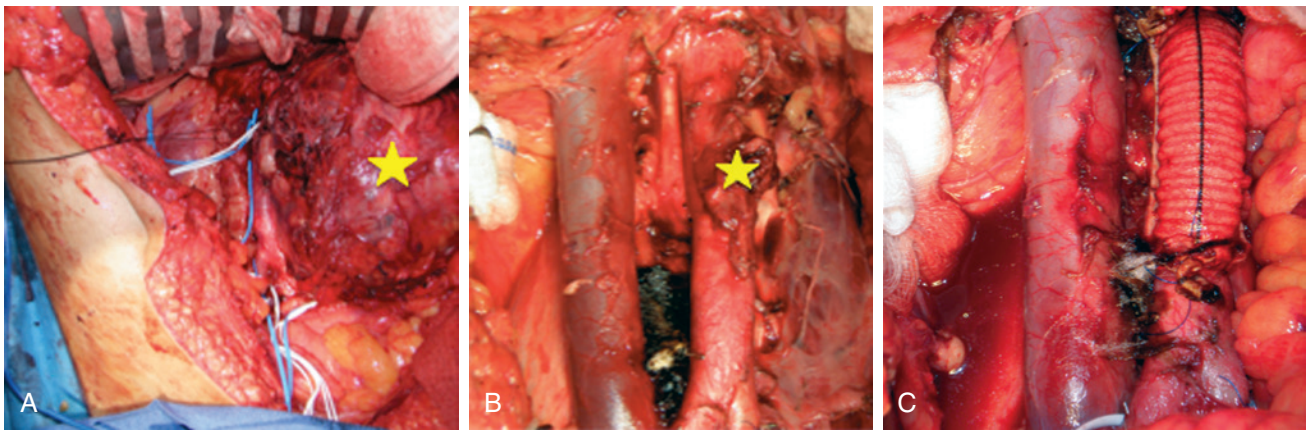


Figure 40.6 A, Large para-aortic mass in a patient with metastatic testicular cancer (star). B, Mass (star) unable to be completely resected from the adventitial wall of the aorta. C, Affected aorta resected and replaced with polytetrafluoroethylene graft.

Anomalous drainage of the kidneys can also be problematic if not recognized. In up to 8% of the population, both an anterior and posterior branch of the left renal vein is present, encircling the aorta. This is also commonly referred to as a circumaortic collar. A somewhat less common variation is a retroaortic left renal vein, which occurs in approximately 3% of the population.[57] Recognition of a retroaortic left renal vein is especially important because it may be mistaken for a lumbar vein and inadvertently ligated. Of note, more than one right renal vein can also be present.

Arterial Complications

The best approach to preventing arterial injury is to have a sound understanding of vascular anatomy. Unlike the venous system, transected major arteries should be repaired in the vast majority of circumstances. The only exception to this rule is the inferior mesenteric artery, which may be divided for better exposure to aortic dissection. Unless the patient has significant atherosclerotic vascular disease, the left colon will receive collateral blood supply through the marginal artery and the arch of Riolan.

During exposure of the retroperitoneum for RPLND, the duodenum and pancreas are reflected cephelad along with the small bowel, cecum, and right colon. Before placing a self-retaining retractor, great care should be taken to ensure the superior mesenteric artery (SMA) is not compressed or injured. A similarly cautious approach must be taken to dissection of a suprahilar mass, where the SMA is again at risk. Failure to promptly recognize an SMA injury leads to ischemic bowel and a generally catastrophic outcome.

Multiple renal arteries occur fairly consistently in about one-quarter to one-third of all patients.[37,39] An accessory or polar renal artery can originate at the level of the renal hilum or at a variable distance caudal to the main renal artery. Accessory right renal arteries that arise caudal to the renal hilum can pass anterior to the vena cava and are at higher risk for injury, especially if not detected on preoperative imaging. Repairing these smaller vessels is very difficult, so they are best avoided.

Injury to the main renal artery is typically more common on the left because the lymphatic drainage on that side is just inferior to the hilum. Intense desmoplastic reaction after chemotherapy or dissection of a large left-sided mass may ultimately result in nephrectomy. In recent reports, 10–14% of patients undergoing pcRPLND will require adjuvant nephrectomy, predominantly on the left.[36,58] The right renal artery is primarily at risk during dissection of bulky interaortocaval masses.

Although injury to the aorta is rare, resection and replacement may be necessary. In the largest series to date, aortic substitution was required in just 1% of 1250 pcRPLND operations.[59] However, a smaller, more recent series cites a much higher rate of 9%, likely as a result of patient selection.[58] The need for repair arises when a subadventitial plane is created in the course of removing a densely adherent mass. Removal of the adventitia along with the mass substantially weakens the aortic wall and may result in postoperative aortic aneurysm or rupture. In cases where large segments of the adventitia are peeled away in the course of dissection, it is generally a good idea to perform aortic substitution with a synthetic graft (Fig. 40.6).[60]

Gastrointestinal Complications

Gastrointestinal complications are fairly rare and can usually be avoided by careful handling of the bowel and placement of retractor blades. Sometimes, mobilization of the duodenum can result in postoperative pancreatitis. This manifests as nausea and vomiting in the setting of elevated amylase and lipase levels. It will resolve with conservative dietary management in the vast majority of cases.

Similarly, excessive manipulation of the bowel or small serosal abrasions may result in postoperative ileus. This happens in approximately 2% of patients undergoing pcRPLND and is more likely to occur as the extent of dissection increases.[5] Conservative management with nasogastric suction and bowel rest is typically effective in resolving this issue.

The bowel can also be directly injured, especially when dissecting the duodenum away from a densely adherent retroperitoneal mass during pcRPLND. If an enterotomy is created, it should be closed in two layers. Furthermore, omental interposition between the injured bowel and the great vessels is prudent in order to prevent formation of an abscess or aorticoduodenal fistula.[60] At the end of the

RPLND, it is important to inspect the bowel so that any injury can be primarily repaired. Lastly, the posterior layer of peritoneum should be loosely reapproximated to avoid bowel adhering to the anterior surface of the retroperitoneal vessels.

Complications of Pelvic Lymph Node Dissection

The removal of pelvic lymph nodes as part of the treatment of muscle invasive bladder cancer, higher risk prostate cancer, or advanced stage penile cancer is a cornerstone in the management of these malignancies. While clearly adding diagnostic and therapeutic value, pelvic lymph node dissection (PLND) also adds substantial morbidity. This morbidity comes in the form of additional operative time, as well as complications specific to lymphadenectomy, such as lymphocele, deep vein thrombosis (DVT)/pulmonary embolism (PE), injury to nerves, or, rarely, injury to major vessels within the pelvis.

In the form that it exists today, PLND is a fairly blunt, non-discriminatory tool, in that the lymph nodes are removed without knowing which, if any, actually harbor cancer. In the current age of imaging, many have attempted to refine the technique by identifying suspicious nodes preoperatively. Unfortunately, both CT and MRI have low sensitivity for detecting lymph node metastases and cannot be used to reliably select patients for PLND.[61,62] Newer imaging modalities such as 11C-choline and 18F-fluoromethylcholine PET/CT showed initial promise, but recent studies do not find that either adds diagnostic efficacy over conventional imaging in prostate or bladder cancer.[63–65]

Therefore, PLND remains the gold standard for identifying and removing lymph node metastasis. In the following section, we describe the complications that are specific to PLND. Complications of surgery for penile cancer will be discussed in a later part of this chapter. Prior to examining each complication, we will first touch on the lack of standardization of PLND in the treatment of prostate cancer, and less so bladder cancer, as this is a significant confounder in interpreting the rates of complications associated with each.

CONSIDERATIONS IN RADICAL PROSTATECTOMY

The decision to perform PLND during radical prostatectomy is an area of significant variability between surgeons and centers. Much of the inconsistency stems from the lack of standardization in guideline statements made by the American Urological Association (AUA), the European Association of Urology (EAU), and the National Comprehensive Cancer Network (NCCN). Although both the EAU and NCCN agree that patients treated for high-risk prostate cancer should undergo PLND, there is inconsistency regarding when it should be performed in intermediate-risk patients. The AUA is more vague, stating only that pelvic lymphadenectomy "is generally reserved for patients with higher risk of nodal involvement."[66,67] The extent of dissection is also not standardized among the three guideline committees. Only the NCCN and the EAU guidelines make recommendations, saying that an extended template should be used if PLND will be performed.[67,68]

The nomenclature regarding the extent of PLND in prostate cancer is also an area of significant variability and confusion among publications. The definition of a limited PLND varies from removal of nodes only between the external iliac vein and obturator nerve, to broader dissections, which also include the nodes below the obturator nerve and around the internal iliac vessels. However, some authors call this a standard, or even an extended, PLND. The most common definition of an extended PLND usually entails the removal of all nodal tissue from around the obturator fossa, as well as the external, internal, and common iliac vessels to the level of the crossing ureter. An extended dissection will also variably include the presacral nodes, which some authors call a super-extended PLND.

Many surgeons believe that the risk of complications increases with the greater extent of PLND. The literature examining this question is conflicting and difficult to interpret because of the inconsistency in terminology used to describe the extent of dissection. Nevertheless, a number of studies report higher complication rates with extended PLND, with much of the increase being driven by the rate of postoperative lymphocele.[69–71] On the other hand, at least one study by Heidenreich et al., showed the complication rate was equivalent between extended and standard PLND in 203 patients.[72] Another study reported that the rate of lymphoceles requiring intervention was actually higher in the standard PLND group.[73]

The oncologic importance of performing PLND is beyond the scope of this chapter. However, despite the potentially increased morbidity with an extended PLND, mapping studies of the lymphatic drainage of the prostate have essentially proven that limited dissections do not adequately control potential prostate cancer landing zones.[74,75] One study cites that up to 63% of positive lymph nodes fall outside the area of standard PLND in patients with node-positive prostate cancer.[74] As a result, the literature has shifted in favor of extended PLND in recent years.

CONSIDERATIONS IN RADICAL CYSTECTOMY

Lymphadenectomy during radical cystectomy for muscle invasive bladder cancer is almost universally accepted as the standard of care. Although primarily comprised of retrospective studies, a recent systematic review of almost 20,000 patients concluded that PLND improves oncologic outcomes over no PLND. Although the proper nomenclature is up for debate, many consider an extended PLND the dissection of all pelvic nodes up to the bifurcation of the aorta. This dissection has been demonstrated in studies to provide an oncologic advantage. A super-extended PLND, which includes dissection of para-aortic and paracaval nodes up to the inferior mesenteric artery, however, has not been convincingly shown to provide further advantage over extended PLND.[76]

Unfortunately, just as in radical prostatectomy, there is substantial heterogeneity in the extent of PLND performed between centers as well as the anatomic boundaries of each type. Furthermore, there are very limited data describing the rates of complications based on extent of PLND during radical cystectomy. For our purposes, the complications of

PLND during radical cystectomy are not significantly different from those encountered during radical prostatectomy. Therefore the following sections apply to both clinical scenarios.

NERVE INJURY

The obturator, genitofemoral, and femoral nerves travel through the pelvis and are at risk for injury during PLND. The obturator and genitofemoral nerves are closely associated with the pelvic lymph nodes, predisposing them to direct injury. In contrast, the femoral nerve is more likely to be damaged as a result of positioning or exposure during the operation. Harming any of these nerves can produce debilitating symptoms that can result in significant patient distress. In certain cases, severe injuries may result in lifelong disability. We will discuss the etiology and prevention of each type of injury in the following sections. Principles of management are similar regardless of injury and will be discussed together at the end.

Obturator

The obturator nerve arises from the anterior rami of the L2–L4 spinal nerves in the lumbar plexus, travels through the fibers of the psoas major, and pierces the medial border of the psoas muscle at the pelvic brim. It then runs along the lateral pelvic sidewall deep to the external iliac vessels, lateral to the internal iliac vessels and ureter, and superficial to the obturator vessels. It eventually leaves the pelvis through the obturator canal with the obturator vessels to provide motor innervation for the medial thigh muscles, which adduct the leg. It also provides sensory innervation to the skin of the medial thigh. Of note, the obturator nerve does not innervate any structures within the pelvis, so there are no branches that are at risk during PLND.

The obturator nerve itself can be injured during the removal of the fibro-fatty lymph node containing tissue surrounding the nerve. Damage can occur in a number of ways, including partial or complete transection, crush injury from direct application of instruments or clips, excessive traction, or the use of electrocautery in proximity to the nerve. The severity of clinical symptoms will depend on the type and extent of injury.

The most common presentation of obturator neuropathy involves altered sensation on the medial thigh, ranging from sensory loss to paresthesias and pain. These symptoms can extend from the groin down to the medial knee. They may be exacerbated by maneuvers that stretch the nerve, which include extension and abduction of the leg. Weakness of adduction and internal rotation of the thigh can be present to varying degrees. Severe weakness can manifest as a gait abnormality characterized by an abnormally abducted and externally rotated ipsilateral hip.[77] If the diagnosis is in doubt, electromyography can be helpful.[78]

The most effective method of preventing obturator nerve injury is to understand the anatomic course of the nerve and its relationship to other structures in the pelvis. Great care should be taken when dissecting and placing clips within the obturator fossa. Small collateral vessels should be controlled before proceeding with the dissection. Lastly, division of the proximal and distal node packet should only be performed after the course of the entire nerve is visualized.

The reported incidence of obturator nerve injury is less than 1% in most studies.[79,80] However, mild symptoms that do not produce significant disability are likely not reported by patients, so the true incidence is almost certainly higher. Although rare, this injury is more likely to occur in patients with prior chemotherapy or pelvic radiation, or tumor involvement of the obturator nodes. The inflammatory reaction associated with these conditions makes dissection of the nerve away from the node packet more difficult.

Severe injuries such as partial or complete transection, recognized intraoperatively, should be primarily repaired with microsurgical techniques at the time of surgery.[81,82] If an end-to-end tension-free primary anastomosis is not possible because of retraction of the transected ends, autologous sural nerve can also be used with good success.[83,84] As long as the nerve is promptly repaired, motor and sensory function is typically restored by 1 year after surgery.

Little is known about the management of patients that have persistent severe weakness and/or pain despite physical therapy. There is some evidence that surgical exploration may identify an unrecognized major injury to the nerve. Repair of the nerve, even months after the initial injury, has resulted in improved adductor muscle strength.[85]

Genitofemoral

The genitofemoral nerve arises from the L1 and L2 spinal nerve roots in the lumbar plexus and pierces the fibers of the psoas muscle. It then runs along the anterior surface of the psoas, where it splits into its genital and femoral branches. The femoral branch travels underneath the inguinal ligament and provides sensory innervation to the upper medial thigh. The genital branch travels into the inguinal canal and supplies sensory innervation to the skin of the anterior scrotum in men and the mons pubis and labia majora in women. It also supplies the motor fibers innervating the cremaster muscle in men.

Damage to the genitofemoral nerve during pelvic lymphadenectomy is most likely to occur where the nerve travels just lateral to the common and external iliac vessels. The key to preventing injury is to start the nodal dissection proximally and to mobilize the iliac vessels medially in order to visualize the nerve. It may be intimately involved with the nodal tissue surrounding the vessels, so a careful split and roll technique should be used.

Femoral

The femoral nerve arises from the anterior rami of the L2–L4 spinal nerves in the lumbar plexus, travels through the fibers of the psoas major, and emerges at its lateral border. It then travels in the groove between the psoas and iliacus muscles until it passes underneath the inguinal ligament to innervate the muscles responsible for hip flexion and extension at the knee. It also supplies cutaneous branches that innervate the anterior and medial lower extremity.

Most commonly, femoral neuropathy results from inappropriate use of a self-retaining retractor in the pelvis, especially when exposing the lateral pelvis for lymphadenectomy. The nerve can be damaged by excessive traction, compression against the pelvic sidewall by the psoas muscle, or by direct compression of the nerve by the blades of the retractor. Femoral neuropathy can also occur with prolonged or exaggerated lithotomy position, which can exert pressure

on the nerve as it passes underneath the inguinal ligament. Lastly, there is some evidence that arterial ischemia to the intrapelvic portion of the nerve can result in neuropathy. This seems to be more common on the left side, where there is less collateral blood supply from the deep circumflex iliac artery.[86]

The role of self-retaining retractors is best highlighted by comparative studies in the gynecologic literature.[87,88] For example, Goldman et al.[88] performed abdominal hysterectomies on over 6000 women and noted the rate of femoral neuropathy fell from 7.5% to 0.7% when a self-retaining retractor was not used. There are also many case studies in the urologic literature that document femoral nerve injury after open radical prostatectomy or cystectomy, implicating self-retaining retractors as the cause.[89–92]

The best method for preventing femoral nerve injuries in open lymphadenectomy is careful, methodical placement of self-retaining retractors. When placed properly, the retractor should only retract the rectus musculature without putting pressure on the psoas muscle. The shortest possible blades should be used, and folded lap sponges should be placed between the blades and the musculature to act as a cushion. The surgeon should check for proper positioning during placement and periodically during the operation.

When using the robotic approach, the risk of femoral neuropathy stems primarily from patient positioning in dorsal lithotomy, or on a split-leg table with extension at the hip to facilitate docking.[93] While this injury can occur during radical prostatectomy without lymphadenectomy, PLND increases operative time. Prolonged positioning in dorsal lithotomy, especially with legs hyperabducted, externally rotated, and flexed at the hip, is a well-established risk factor for lower extremity neuropathies postoperatively.[94] Fortunately, with the newer robotic platforms, the patient is able to remain supine while the robot docks alongside the patient, instead of at the feet. This should minimize the risk of femoral neuropathy in these patients.

Most commonly, femoral neuropathy manifests as difficulty with ambulation in the immediate postoperative period, along with altered sensation over the anteromedial thigh. The most reliable clinical signs are weakness of the quadriceps muscle and an absent or diminished patellar reflex.[95] Patients complaining of significant pain that also have a bleeding diathesis or are on anticoagulation therapy should potentially undergo cross-sectional imaging to rule out a perineural hematoma.[96]

MANAGEMENT OF PELVIC NERVE INJURIES

Regardless of the nerve that is injured, there are a few basic principles of management that should be followed. A neurologist and rehabilitation specialist should be involved early in the care of patients with neurologic symptoms postoperatively. This is important for the purposes of making the correct diagnosis and initiating prompt physical therapy, if necessary. It is also important from the standpoint of properly documenting baseline signs and symptoms, enabling an accurate assessment of the patient's comparative clinical course during treatment.

Management typically involves a multimodal, multispecialty approach. The mainstay of treatment for motor dysfunction is physical therapy, which should begin as soon as possible in the postoperative period. Patients with sensory dysfunction such as pain or paresthesias are typically managed in a stepwise approach, beginning with NSAIDS. Alternative oral medications are essentially those used with all forms of neuropathic pain and include opioids, tricyclic antidepressants, selective serotonin/norepinephrine reuptake inhibitors, and antiepileptics. Topical lidocaine patches have also been used. More invasive options typically involve nerve blocks with an anesthetic solution.[97]

The time course for resolution of symptoms is highly variable and depends on the severity of injury. Minor paresthesias can resolve in days to weeks. Alternatively, pronounced motor weakness can persist for months, years, or, in some cases, indefinitely. Although recovery is dependent on a variety of clinical factors, EMG can be a useful prognostic tool. If EMG suggests anatomic denervation, some form of disability is likely to persist.[98]

LYMPHOCELE

The formation of a pelvic lymphocele is a common complication after pelvic lymph node dissection (Fig. 40.7). A lymphocele is a collection of lymphatic fluid surrounded by a fibrous wall without an epithelial lining. Unlike blood vessels, lymphatic vessels do not contain smooth muscle within their walls and therefore cannot constrict in response to injury or transection. The continued flow of lymph from injured afferent lymphatic channels into a confined space is the mechanism believed to be responsible for lymphocele formation.

While lymphoceles are common after pelvic surgery, only a small percentage become clinically apparent. In studies where patients underwent imaging shortly after surgery, the rate of all lymphocele formation after a laparoscopic approach varies from 30% to 53%[99–102] compared to 15% to 61%[101,103] after open surgery. The large variation in asymptomatic lymphoceles is likely a result of differing patient characteristics and methods of detection. Studies that employed ultrasound typically detect fewer lymphoceles because of the lower sensitivity of ultrasound when



Figure 40.7 Large pelvic lymphocele anterior to bladder after radical prostatectomy and pelvic lymph node dissection. Patient presented with abdominal fullness and urinary frequency.

compared to CT. Symptomatic lymphoceles are much less common. The exact rates vary between studies, but appear to be fairly equivalent between laparoscopic and open lymphadenectomy (0–8%[100,104–106] vs 3–10%[72,101,104,107]).

There are a number of clinical and surgical factors that have been associated with increased risk of lymphocele formation. It was previously believed that minimally invasive surgery, done through the peritoneum, would prevent lymphatic fluid from accumulating in a closed space and be protective against the formation of lymphocele. A few retrospective series support this notion,[108,109] including one large population-based study of Medicare patients where the rate of lymphocele formation was 1.3% versus 2.2% in favor of the minimally invasive group.[110] Unfortunately, the retrospective data are difficult to interpret because of the wide variation in patient selection and extent of PLND. There are currently no randomized trials comparing the two approaches, so no clear answer exists.

One might expect that an extended PLND, which requires a wider anatomic dissection and removal of a larger number of nodes, would carry a higher risk of developing lymphocele postoperatively. Again, the data are mixed. Musch et al. cite a threefold increased risk of lymphocele in patients undergoing extended PLND in their retrospective cohort of 1380 patients.[79] However, other retrospective studies show no significant difference.[73,111]

Administration of perioperative heparin has been investigated as a possible risk factor for lymphocele formation, with mixed results. A number of earlier studies have reported increased lymphocele formation in those receiving heparin prophylaxis.[112–114] More contemporary studies, however, suggest that the risk is equivalent to those not receiving heparin.[115,116] The consensus among most urologists is to continue to administer heparin as the morbidity of DVT and PE outweigh the small potential increased risk of lymphocele formation, especially after radical cystectomy.

Lastly, the placement of a pelvic drain at the conclusion of surgery was thought to be protective against developing a lymphocele by providing a means for the leaking lymphatic fluid to escape. Danuser et al.[108] demonstrated that the risk of lymphocele was significantly reduced if a drain was left until postoperative day 7. However, most surgeons remove the drain in the first few postoperative days to minimize patient discomfort and other complications. Furthermore, other studies showed no increased risk of lymphocele in patients who had no pelvic drain placed.[117,118]

Most symptomatic lymphoceles begin as a vague sensation of abdominal fullness. As they increase in size, they can cause a variety of clinical symptoms as they encroach on anatomic structures within the pelvis. Gastrointestinal symptoms can range from constipation from pressure on the colon to frank ileus, resulting in nausea and vomiting. Urinary symptoms can include urinary frequency from compression of the bladder or, less commonly, hydronephrosis and flank pain from compression of the ureter. Impingement on nerves within the pelvis can result in pain or lower extremity weakness in the distribution of a specific nerve. Lastly, lymphoceles can impair venous return from the genitalia and lower extremities resulting in edema and, sometimes, DVT. Fever associated with lymphocele is typically a sign of superinfection and will necessitate drainage.

Given the variability in presenting symptoms, a heightened level of suspicion must be maintained after prostatectomy or cystectomy to make this diagnosis. Typically, lymphoceles will not be apparent on physical examination until they become very large, at which point one may appreciate a lower abdominal mass. Ultrasound imaging is easy to perform, spares the patient ionizing radiation, and can easily detect large lymphoceles, which are anechoic. However, it is also heavily operator dependent and not as sensitive as abdominal/pelvic CT, which is the gold standard test for diagnosis.

Many lymphoceles will resolve with time and can be managed expectantly, especially when symptoms are mild. The caveat to this is a lymphocele that appears to compress pelvic veins, as this can lead to deep venous thrombosis and further morbidity. For those that require intervention, a number of options are available. Most pelvic lymphoceles are readily accessible to percutaneous drainage and drain placement by an interventional radiologist, typically resulting in rapid resolution of the patient's symptoms. Cell count of the aspirated fluid will show a predominance of lymphocytes and the creatinine will be consistent with serum (in contrast to elevated fluid creatinine in the case of urinoma). Once in place, drain output should be recorded and the drain should not be removed until the output is low. Reported rates of resolution with percutaneous drainage are in the order of 50–97%, and the drain is kept in place for an average of about 3 weeks.[119–121]

If drain output remains high, indicating a persistent lymph leak, a sclerosing agent such as ethanol,[122] povidone-iodine,[120,123] doxycycline,[124] fibrin sealant,[125] etc., may be injected into the lymphocele. The addition of a sclerotic agent does successfully treat most patients that do not respond to simple drainage alone, especially after additional rounds of sclerosis. Importantly, the overall success rate for multiloculated lymphoceles is much lower and may require a different approach.[121]

Laparoscopic marsupialization is an effective alternative to percutaneous drainage.[126–128] Marsupialization involves incising the roof of the lymphocele to create a window into the peritoneum. This can be employed either as primary therapy (especially in cases of multiloculated lymphocele) or after failure of percutaneous drainage and sclerosis. Success rates were as high as 97% in one large study,[128] in which half of patients were refractory cases. This approach is generally safe, but injury to the ureter, bladder, or pelvic vascular can occur.

A number of surgical techniques have been investigated that may help to prevent postoperative lymphocele. A few of these methods include the use of FloSeal in the area of PLND,[129] peritoneal fenestration during extraperitoneal PLND,[109] the use of a TachoSil surgical patch near the femoral canal and in the obturator fossa,[130] as well as a rotational flap of bladder peritoneum brought down into the deep pelvis.[131] While many of these studies show an advantage in the experimental arm, they have been small, single institution series that have not been well validated. At this time, it is controversial whether the utilization of these techniques, which are often costly and increase operative time, justifies the small potential decrease in symptomatic lymphoceles.

Regardless of whether any specific technique or material is used to prevent lymphocele formation, it is important to

maintain sound surgical principles during PLND. As the lymph node packet is dissected, careful attention should be paid to avoiding excessive traction, which may tear small lymphatic vessels. Transected lymphatics, especially larger ones at the proximal and distal ends of the packet, should be meticulously controlled with surgical clips. This can potentially be better accomplished in minimally invasive procedures, where visualization of the complete extent of the delicate lymphatics is excellent.

THROMBOEMBOLIC EVENTS

Deep vein thromboembolism and PE are rare but potentially lethal complications of radical prostatectomy and cystectomy. It is worth mentioning that the performance of pelvic lymphadenectomy during radical prostatectomy significantly increases the risk of DVT and PE.[132,133] In one study, the risk of DVT increased eightfold and the risk of PE increased sixfold, compared to prostatectomy without PLND. Furthermore, the risk of rehospitalization for PE is many-fold higher in patients receiving lymphadenectomy, although the absolute risk of rehospitalization for PE remains low at around 1.3%. There is no difference in DVT or PE between patients receiving open versus robotic prostatectomy and PLND.[134]

The increased incidence of thromboembolic events should not deter surgeons from performing PLND in men with prostate cancer at increased risk for nodal metastasis. However, it is important to remain vigilant; any patient with oxygen desaturation or respiratory complaints after surgery must be evaluated thoroughly and promptly. The American Society of Clinical Oncology currently recommends pharmacologic prophylaxis for all patients with cancer undergoing major abdominal or pelvic surgery starting before the operation and continuing for at least 7–10 days.[135]

It is important to keep in mind that the majority of thromboembolic events occur after discharge from the hospital.[132,136] As a result, some centers routinely use extended thromboprophylaxis for 1 month in patients undergoing cystectomy. After radical prostatectomy and PLND, extended thromboprophylaxis is not routinely used, but may be warranted in some men with additional risk factors.

VASCULAR INJURY

The pelvic lymph nodes are found in close association with the major vascular structures of the pelvis. Vascular injury can certainly occur, but is rare. In general, there is no substitute for careful dissection and retraction of vascular structures away from the area of dissection. If PLND cannot be performed safely because of dense inflammation, significant adenopathy, or altered tissue planes, consider aborting the procedure, especially in cases with questionable benefit such as low-risk prostate cancer. If benefit is considerable and a PLND must be performed, it is wise to involve a vascular surgeon, in case a complicated reconstruction becomes necessary.

Inadvertent transmission of electrocautery current resulting in vascular injury has been reported during robotic pelvic lymphadenectomy. This is thought to occur secondary to failure of the insulating sheath, known as the tip cover accessory (TCA), of the monopolar scissors.[137] Malfunction of the TCA results in arcing current that can damage surrounding structures. This has been shown to occur almost exclusively with first-generation TCAs and is more likely to occur with increased wrist angulation. The second-generation TCA released in 2012 has not been associated with this problem to date.[138]

Complications of Inguinal Lymph Node Dissection

Penile cancer spreads in a predictable, stepwise fashion along the route of lymphatic drainage of the penis. Metastatic cells travel to the superficial, followed by the deep inguinal nodes, before eventually extending into the ipsilateral pelvic nodes. The surgical removal of these nodes is an indispensable part of the management of invasive penile carcinoma. The presence or absence of cancer within the local nodes provides valuable prognostic information.[139–141] Of equal importance, inguinal lymph node dissection (ILND) is associated with a survival advantage, even when the nodes are clinically not involved, and can cure a significant portion of men.[142–144]

Over the last few decades, the indications for ILND have evolved. Prior to the mid-1980s, ILND was mostly performed for clinically palpable disease using the "standard template." The borders of this dissection are a line joining the anterior superior iliac spine (ASIS) and pubic tubercle superiorly, a vertical line 20 cm caudal to the ASIS laterally, a line 15 cm caudal to the pubic tubercle medially, and a horizontal line joining the two vertical margins inferiorly. Nodal tissue deep to the fascia lata in the area of the femoral vessels is also removed, so that the dissection is essentially in continuity with the pelvic lymph nodes. The saphenous vein is typically ligated at its insertion into the femoral vein, and the sartorius muscle is transposed to cover the exposed femoral vessels.

Dissection of clinically negative groins beginning in the mid-1980s mandated a less morbid technique than the standard ILND used at the time, since up to 80% of patients were being overtreated.[141] In 1988, Catalona described the "modified template" ILND for patients with clinically negative groins,[145] which significantly decreased complications and is still used today. Compared to the standard template dissection, the template proposed by Catalona included a narrower field, bordered by the lateral edge of the femoral artery laterally, the external oblique muscle above the spermatic cord superiorly, the adductor longus muscle medially, and the fascia lata just distal to the fossa ovalis inferiorly. The saphenous vein is preserved, the sartorius muscle does not need to be transposed, and a smaller skin incision can be used, making this a significantly less morbid procedure.

In a similar, concurrent effort to detect clinically occult metastasis with minimal added morbidity, dynamic sentinel node biopsy was developed.[146] This approach relies on the belief that lymphatic spread of cancer cells occurs in a stepwise manner, first migrating to the sentinel lymph node or nodes before continuing on to more distant nodes. A formal inguinal lymphadenectomy is performed only if intraoperative frozen section of the sentinel node is positive. Although this technique initially had unacceptably high false-negative rates, it has been refined over the years. In



Figure 40.8 Penile squamous cell carcinoma with large necrotic inguinal mass at presentation.

modern series, the false-negative rate is as low as 5–7%, albeit in a few high-volume specialized centers.[147,148]

Currently, there are three distinct indications for performing ILND. The first is performed in patients with clinically negative nodes and is termed *prophylactic ILND*. Many urologists prefer to use the modified template in this setting, while certain specialized centers will perform dynamic sentinel node biopsy. The second indication is for patients with clinically apparent nodes. In these cases, a standard template for the ipsilateral or bilateral groins is typically used. The last indication is in the setting of bulky, fixed disease, frequently after the administration of neoadjuvant therapy. This is considered to be a palliative dissection and may include large segments of involved inguinal skin, spermatic cord, inguinal ligament, testicle, or other local tissues. Local flaps for coverage are often needed in this last scenario (Fig. 40.8).

The morbidity of ILND largely depends on the indication and extent of dissection.[149,150] Multiple large studies demonstrate that complications after standard template dissections are common. Overall incidence of complications in most studies varies from 41% to 82%, although one recent series of 340 procedures reports a 10% complication rate.[149,151–154] In contrast, a much lower rate of 7–33%[149,152] can be expected with modified dissections. In recent years, minimally invasive approaches have been incorporated in an attempt to reduce morbidity from ILND.[155] Tobias-Machado et al. performed ILND in 10 patients, comparing a minimally invasive approach in one groin with an open approach in the contralateral groin. They found the overall complication rate to be 20% versus 70%, and cutaneous complications occurred at a rate of 0% versus 50%, respectively.[156] The experience with robotic ILND is still immature, but initial studies are promising.[157,158]

CUTANEOUS COMPLICATIONS

A large proportion of early complications after ILND are cutaneous, manifesting as skin infection or skin necrosis,

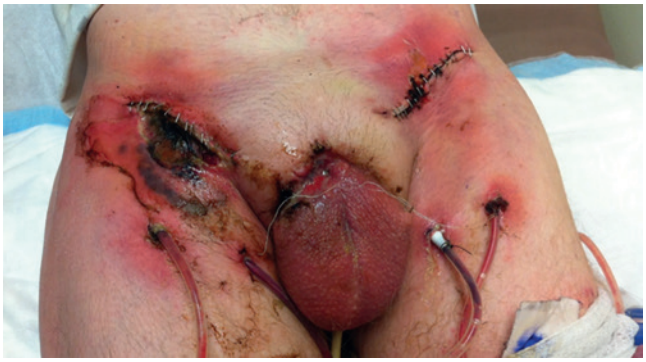


Figure 40.9 Extensive cellulitis and wound necrosis bilaterally after penectomy and inguinal lymph node dissection for penile cancer.

with or without wound dehiscence (Fig. 40.9). Both are a result of the devascularization that occurs in the process of developing skin flaps. During the dissection, the branches of the common femoral artery supplying the overlying skin are often ligated, so viability depends on the small anastomotic vessels running in the Camper's fascia. Furthermore, there is impaired lymphatic drainage, as well as seromas and hematomas that often form in the dead space created by the raised skin flaps, all of which contribute to the development of infection.

Certain surgical tenets should be followed in order to minimize the risk of cutaneous complications. Preoperative parenteral broad-spectrum antibiotics should be administered, and the surgical field should be thoroughly washed and prepped. Care should be taken to limit the mobilization of skin flaps to the boundaries required for dissection, regardless of the template used. Fine skin hooks are used when raising the flaps and the maximum thickness of superficial fascia should be preserved, while ensuring that no nodal tissue is left behind. At the end of the case, the skin flaps should be anchored to the underlying fascia to decrease dead space and to decrease tension on the skin edges. Meticulous hemostasis should be maintained to prevent hematoma formation. Lastly, it is important to debride any necrotic tissue at the skin edge prior to closure.

Management of wound infection without dehiscence is adequately treated with oral or parenteral antibiotics in most cases. Skin edge necrosis and minor flap necrosis can usually be managed with local wound care and bedside debridement. There is some evidence that negative pressure wound therapy may speed time to closure in this setting.[159] Larger defects may need debridement in the operating room and coverage with a split-thickness skin graft once the tissue begins to granulate. Primary reconstruction at the time of ILND with a tensor fascia lata pedicled flap, anterolateral thigh flap, or vertical rectus flap may be indicated in patients with large defects who are at high risk for necrosis postoperatively.[160]

One of the major advantages of minimally invasive ILND is that cutaneous complications are largely avoided. The ability to forgo a large incision near the inguinal crease for laparoscopic incisions on the abdomen or distal thigh seems to significantly decrease rates of infection. A large review of 249 minimally invasive groin dissections for vulvar cancer reported wound infection in 1.2% of cases.[155] Many smaller reports in the urologic literature report no skin

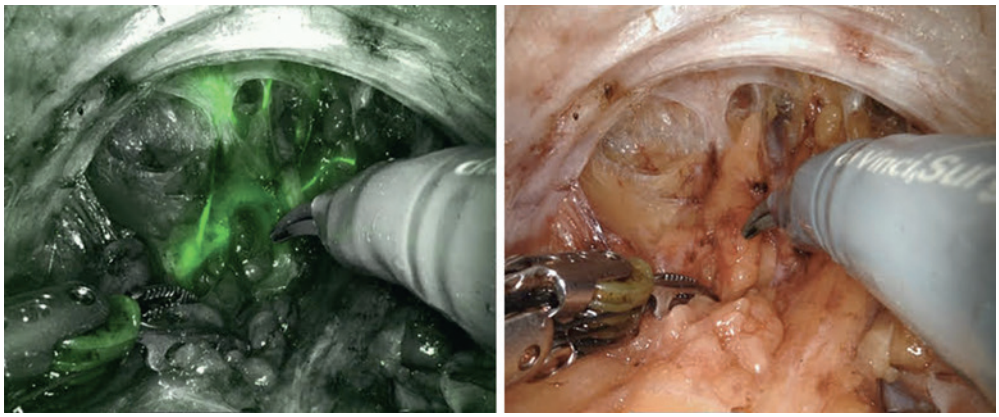


Figure 40.10 Injection of indocyanine green at the base of the penis to improve visualization of lymphatic tissue during robotic inguinal lymph node dissection.

complications with this technique.[156,161] In our initial experience, there have been no cutaneous complications in seven robotic groin dissections.

LYMPHATIC COMPLICATIONS

Disruption of lymphatic channels during ILND can result in lymphocele formation in a small percentage of patients. In an effort to prevent lymphoceles and seromas, most urologists leave a suction drain or drains at the end of the procedure, although there are no randomized trials to support this practice.[162] Drains are typically removed when output is less than 30–50 mL/day. If a lymphocele forms after removal of the drain, it should be drained only if infected or symptomatic. For persistent or recurrent lymphoceles, identification of open lymphatic channels with an injected blue dye and subsequent ligation has been successful in many cases.[163] For a detailed discussion on the management of lymphoceles, please see the earlier section on pelvic lymphadenectomy. Of note, applying fibrin sealant to the area of dissection does not appear to decrease the incidence of fluid collections in the setting of ILND.[164]

The most significant long-term complication of ILND is the development of chronic lymphedema, occurring in 4–22% of patients in contemporary series.[149,152,154,165,166] It clinically manifests as swelling of the affected limb, usually with increased turgor, hyperkeratosis, and papillomatosis. It can lead to significant disability, with many patients experiencing pain, heaviness, impaired function, and recurrent infections. Symptoms may be severe, impairing mobility and preventing patients from working.

There has been significant interest in risk factors and techniques to minimize the development of lymphedema. Larger extent of inguinal dissection, dissection of pelvic nodes, adjuvant radiation therapy, and increased BMI are risk factors.[151,167] Sparing the saphenous vein has been shown to decrease short- and long-term incidence of lymphedema.[168,169] Most urologists recommend leg elevation and lower extremity compression stockings as a method of prevention in the immediate postoperative period. However, a recent randomized controlled trial by Stuiver et al. did not show any benefit.[170] During robotic ILND at our center, we inject indocyanine green (ICG) at the base of the penis and blue dye in the first interweb of the ipsilateral foot to visualize the draining lymphatic vessels of the tumor and ipsilateral lower extremity, respectively. Careful ligation of lymphatics draining the tumor may prevent lymphocele formation, and avoidance of lymphatics draining the foot can potentially reduce incidence of lymphedema of that extremity (Fig. 40.10).

Treating chronic lymphedema is difficult, but advances in microsurgical therapies show promise in refractory cases. Treatment should begin with lower extremity compression devices and lymphatic massage, which are the cornerstones of conservative management.[171] Since muscle contraction is normally responsible for assisting the flow of lymph, regular exercise may be helpful.[172] Also, weight loss for obese patients may decrease the hydrostatic pressure opposing the flow of lymph.[173] For patients that have significant disability despite conservative measures, lymphaticovenous anastomosis and vascularized lymph node transfer are available options.[174] When applied to properly selected patients, these procedures can reduce the need for compression stocking use and the incidence of cellulitis.[175]

DEEP VEIN THROMBOSIS

Inguinal lymph node dissection is associated with rates of DVT as high as 6–12% in standard template dissections.[152,176,177] Intermittent pneumatic compression devices should be routinely applied prior to surgery to help mitigate this risk. Early ambulation is advisable for patients not undergoing simultaneous flap reconstruction. Heparin administration perioperatively is more controversial, due to concern for postoperative seroma, hematoma, or lymphocele formation. Anticoagulation practices are center specific and no high-quality studies exist supporting or refuting heparin use in this clinical scenario. In our tertiary care center, we do routinely administer subcutaneous heparin prior to ILND.

References

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Chapter 40 Questions

1. When performing a "nerve-sparing" retroperitoneal lymph node dissection, which statement is TRUE regarding the dissection of the sympathetic nerves in the retroperitoneum?
   a. The right sympathetic chain travels posterior to the IVC while the left travels posterolateral to the aorta
   b. The sympathetic nerves within the aortic plexus consist of pre-ganglionic nerve fibers
   c. The sympathetic splanchnic nerves innervating the pelvic viscera most commonly originate from L3 and L4
   d. Splanchnic nerves overlying the IVC must be isolated prior to performing the split and roll technique to remove nodal tissue
   e. Damage to the sympathetic splanchnic nerves may result in difficulty achieving adequate erections postoperatively

2. All of the following are accepted methods for the management of chylous ascites after retroperitoneal lymph node dissection EXCEPT:
   a. Medium chain triglyceride diet
   b. Complete bowel rest and total parenteral nutrition
   c. Octreotide
   d. Peritoneovenous shunting
   e. Bipedal lymphangiography and injection of iodinated poppy seed oil

3. Which of the following is/are TRUE regarding the vascular anatomy of the retroperitoneum during retroperitoneal lymph node dissection?
   a. A retroaortic renal vein is important to identify because it may be mistaken for a lumbar vein
   b. Approximately one in ten patients may possess multiple renal arteries
   c. The inferior mesenteric artery may be safely transected in the majority of patients for better exposure to the aortic dissection
   d. a and c
   e. All of the above

4. A 72-year-old woman has weakness of right leg flexion after an open cystectomy and ileal conduit creation. Which statement is TRUE regarding the nerve injured in this patient?
   a. The cutaneous branches of this nerve innervate the posterior and lateral aspects of the right lower extremity
   b. The nerve emerges to travel at the medial aspect of the psoas muscle after it pierces through its fibers
   c. Injury to this nerve is most likely to occur as a result of using a self-retaining retractor in the pelvis
   d. The length of the operation does not affect the incidence of injury to this nerve
   e. Injury to this nerve can result from prolonged lateral pressure at the knee while in dorsal lithotomy

5. The right obturator nerve is transected during dissection of the pelvic lymph nodes in a 58-year-old man undergoing robotic prostatectomy. All of the following are appropriate next steps EXCEPT:
   a. Primary end-to-end anastomosis of the nerve using microsurgical technique
   b. Creation of a sural nerve interposition graft to bring the two cut ends together if a primary tension-free anastomosis is not possible
   c. Delayed repair of the nerve 3 months after completion of the robotic prostatectomy
   d. Early postoperative consultation with a neurologist and rehabilitation specialist
   e. Early postoperative initiation of physical therapy

6. Which of the following symptoms may be present in a patient presenting with a pelvic lymphocele after radical prostatectomy?
   a. Urinary frequency
   b. Flank pain
   c. Lower extremity weakness
   d. Lower extremity edema
   e. All of the above

7. A 62-year-old man presents to the emergency department with vague abdominal fullness and low-grade fever 3 weeks after radical prostatectomy. CT scan reveals a left-sided lymphocele compressing the left common iliac vein. Which of the following are appropriate management options for this patient?
   a. Observation
   b. Percutaneous drain placement by interventional radiology
   c. Laparoscopic marsupialization in the operating room
   d. b and c
   e. All of the above

8. What is the approximate incidence of hospitalization for pulmonary embolism after pelvic lymphadenectomy?
   a. 0.1%
   b. 0.5%
   c. 1%
   d. 5%
   e. 10%

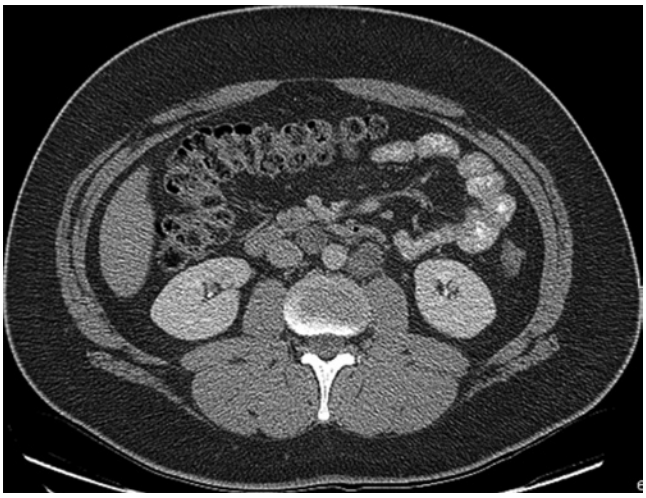
9. Which of the following is NOT an important surgical principle to prevent cutaneous complications when performing inguinal lymph node dissection?
   a. Administration of parenteral preoperative antibiotics
   b. Ten-minute scrub of the operative field with a chlorhexidine solution
   c. Preservation of the maximum thickness of superficial fascia while still removing all nodal tissue
   d. Anchoring skin flaps to the underlying fascia to decrease dead space
   e. Debridement of necrotic skin edges prior to closure

10. Which of the following is NOT TRUE of lower extremity lymphedema that develops after inguinal lymph node dissection?
    a. It resolves completely within 1 month after surgery in most patients

b. It can lead to significant disability and time missed from work
c. It can result in pain, heaviness, or recurrent infections in that limb
d. The cornerstones of management are compression stockings and lymphatic massage
e. Vascularized lymph node transfer is a treatment option in refractory cases

Case Study 1

A 26-year-old man presents to the office with 6 months of testicular pain and is found to have a 3-cm right testicular tumor. A staging CT of his abdomen and pelvis reveals a 8-cm paracaval mass. A chest CT is negative. He undergoes a right radical orchiectomy, and pathologic examination reveals a nonseminomatous germ cell tumor with primary embryonal component. His postorchiectomy alpha fetoprotein (AFP) and lactate dehydrogenase (LDH) remain elevated. He is referred to an oncologist and receives four cycles of etoposide + cisplatin. After chemotherapy his markers normalize, but a follow-up CT scan demonstrates enlarged residual interaortocaval and aortic nodes (Case Figs. 40.1 and 40.2). The patient is scheduled for retroperitoneal lymph node dissection.



Case Figure 40.1



Case Figure 40.2

1. Upon entering the retroperitoneum there is a dense desmoplastic reaction and it is difficult to isolate the lumbar veins. Which of the following is/are true regarding the anatomy of the lumbar veins?
   a. There are always three or four paired infrarenal lumbar veins
   b. Two or more lumbar veins may combine into a common trunk before draining into the inferior vena cava (IVC)
   c. A lumbar vein can occasionally drain into the left renal vein rather than the IVC
   d. b and c
   e. All of the above

2. During dissection of the adherent nodes, the left renal vein is inadvertently lacerated. After obtaining control of the vessel, examination reveals that the vein is half transected about 2 cm distal to its insertion into the IVC. The patient is known to have two functioning kidneys. Which of the following is the most appropriate next step?
   a. Immediately repair the vein with a 4-0 nonabsorbable monofilament suture
   b. Place an interposition Dacron graft
   c. Ligate the vein with surgical clips, leaving the left kidney in place to drain via collateral venous circulation
   d. Left nephrectomy
   e. None of the above

3. In some cases of post chemotherapy retroperitoneal lymph node dissection, it is impossible to dissect the nodal mass off of the IVC. In these cases, which of the following statements is NOT true?
   a. The IVC can be narrowed to up to one-third of its normal diameter during primary repair without grafting
   b. In the setting of chronic IVC occlusion by tumor, the IVC can usually be ligated without significant patient morbidity
   c. If the IVC is ligated, it is critical to spare collateral venous circulation in the area

d. In the setting of acute IVC ligation without prior occlusion, many patients will experience symptomatic lower extremity edema and/or stasis ulcers
e. If the IVC is to be reconstructed, a polytetrafluoroethylene graft is preferred

Case Study 2

A 59-year-old man with a history of hypertension, hyperlipidemia, and Gleason 4+4=8 prostate cancer undergoes an uncomplicated radical prostatectomy and pelvic lymph node dissection. His catheter is removed on postoperative day 7. Two weeks after surgery the patient develops severe urinary frequency and unilateral right leg swelling. In the emergency department, the patient's vital signs are normal. His white blood cell count and creatinine are both within normal limits. A urinalysis is sent, which is not consistent with a urinary infection. A noncontrast CT scan of the abdomen and pelvis reveals a large pelvic fluid collection (Case Fig. 40.3).

1. A drain is placed into the fluid collection, and the fluid is sent for analysis. Which of the following laboratory values would one expect to confirm the diagnosis of lymphocele?
   a. High fluid lipase
   b. High fluid lymphocyte count
   c. Fluid creatinine more than twice that of serum
   d. b and c
   e. All of the above



Case Figure 40.3

2. Seven days after placement of the drain, the output continues to be over 150 mL/day. Which of the following has been successfully used as a sclerosing agent?
   a. Ethanol
   b. Povidone-iodine
   c. Doxycycline
   d. Fibrin sealant
   e. All of the above

3. Which of the following is NOT a previously attempted technique to reduce the incidence of lymphoceles after lymphadenectomy?
   a. FloSeal placed in the area of lymphadenectomy
   b. Peritoneal fenestration during extraperitoneal lymphadenectomy
   c. Rotational flap of bladder peritoneum brought down into the deep pelvis
   d. Heparin injected into the arm instead of the leg immediately before surgery
   e. Intraoperative lymphangiography to detect lymph leaks at time of lymphadenectomy

Answers

1. **a.** The sympathetic nerves within the aortic plexus consist of post-ganglionic fibers. The sympathetic nerves supplying pelvic nerves most commonly originate from L1 and L2. In contrast to the aorta, there is usually no significant nerve tissue overlying the inferior vena cava. Damage to sympathetic nerves results in failure of emission, not erection.
2. **d.** Peritoneovenous shunting is an invasive measure for refractory chylous ascites that is associated with significant morbidity. It would only be indicated if all other measures listed here were to fail.
3. **d.** Approximately one quarter to one third of patients possess multiple renal arteries.
4. **c.** The nerve in question is the femoral nerve, which is responsible for leg flexion at the thigh and extension at the knee. It also gives off cutaneous branches that innervate the anterior and medial lower extremity. It is most often injured by inappropriate placement of a self-retraining retractor during open cystectomy.
5. **c.** Transection of the obturator nerve during prostatectomy can be highly morbid for the patient. Immediate repair is indicated as well as early consultation with a neurologist and rehabilitation specialist.
6. **e.** Large postoperative lymphoceles can compress the bladder or ureter as well as pelvic nerves or veins. This can potentially result in any one or combination of the symptoms listed.
7. **d.** This man likely has an infected lymphocele as he is presenting with low-grade fever. Observation is not appropriate for infected lymphoceles.
8. **c.** The incidence of symptomatic PE is approximately 1% after pelvic lymphadenectomy.
9. **b.** There is no published evidence that increasing the preoperative scrub time decreases the incidence of complications after inguinal lymph node dissection.

10. **a.** Lower extremity lymphedema is a morbid complication of inguinal lymph node dissection and is notoriously difficult to treat. It may require many months of intensive therapy, and may never completely resolve.

CASE STUDY 1

1. **a.** The number of infrarenal lumbar veins is highly variable between patients, varying from 0–4.
2. **a.** In general, partial lacerations to the left renal vein should be repaired if feasible, even in patients with two functioning kidneys, in order to preserve renal function. If the left renal vein is completely transected or avulsed, the kidney may still remain viable if significant collateral circulation has developed from a chronically occlusive mass.
3. **a.** It has been well demonstrated that the IVC can be narrowed to one half of its normal diameter during repair without significant adverse consequences.

CASE STUDY 2

1. **b.** This patient has a postoperative lymphocele. A high fluid lymphocyte count is diagnostic of a lymphocele. Fluid creatinine more than twice that of serum is indicative of a urinoma.
2. **e.** Many substances have been trialed as sclerosing agents for postoperative lymphoceles, including all of those listed.
3. **e.** Lymhpangiography has been utilized postoperatively to detect the area of leak in chylous ascites. It has not been described at the time of initial surgery.

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41 Complications of Radical Cystectomy and Urinary Diversion

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CHAPTER OUTLINE

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KEY POINTS

1. Radical cystectomy is associated with a high rate of complications.
2. Contemporary reporting criteria group complications by organ system and define them according to severity.
3. There are several risk factors for complications, including comorbidity and age.
4. Several techniques, including enhanced recovery pathways, restricted fluid protocols, laparoscopic approaches and referral to high-volume centers, may help minimize complications.

Introduction

Radical cystectomy (RC) with urinary diversion has been the treatment of choice for high-risk bladder cancer for over 50 years.[1] The initial experience with RC was associated with a 14% mortality rate, and over 50% of patients experienced early complications.[2] With advances in anesthesia, staging, patient selection, and surgical technique, there has been an improvement in many surgical outcomes. However, RC continues to be associated with substantial short- and long-term morbidity.

Radical cystectomy patients are generally elderly and have multiple medical comorbidities.[3–6] Surgery can take from 4 to 7 hours followed by a hospital stay of 6–17 days.[7–12] As a result of both the complexity of surgery and patient-related factors, 29–68% of patients experience an early postoperative complication and 1–10% suffer a postoperative mortality.[3–23]

There are many explanations for the wide ranges of complications reported after RC. However, the most important is the method by which complications are identified, classified, and described. In 2002 Martin et al. proposed several criteria that can be used to assess the quality of reporting for surgical complications (Box 41.1).[24] This includes the requirement to define the type and severity of complications, which can be accomplished using a method such as the Clavien-Dindo classification system (see Table 8.2).[25] These criteria are intended to standardize complication reporting

and allow for a more accurate comparison of outcomes across institutions. When several studies that reported RC complications were evaluated based on these criteria, the quality of complication reporting was very low.[26]

By using standard reporting criteria and extending the postoperative period to 90 days, significantly more early complications are observed after RC.[5] Furthermore, although population-level studies that report postoperative morbidity are useful for their large numbers and generalizability, they have limited sensitivity to detect, grade, and categorize the vast array of complications that can occur following RC, resulting in lower complication rates.[8,17,18] Reporting of outcomes is discussed in detail in Chapter 8. Herein, we describe the prevalence of the more common and serious early postoperative complications among contemporary RC cohorts and discuss methods for diagnosis, treatment, and prevention.

Box 41.1 Criteria for Quality Reporting of Surgical Complications[24]

- Method of accruing data defined
- Duration of follow-up indicated
- Outpatient information included
- Definitions of complications provided
- Mortality rate and causes of death listed
- Morbidity rate and total complications indicated
- Procedure-specific complications included
- Severity grade utilized
- Length-of-stay data
- Risk factors included in the analysis

Prevalence and Risk Factors

Using modern reporting methods 49–68% of patients experience at least one complication within 90 days of surgery (Table 41.1). Extending the time frame within which complications are measured is critical, as nearly 20% of patients will have complications after 30 days, some of which are severe.[5] Close outpatient follow-up is important as over half of complications occur following hospital discharge, either in the outpatient setting or during subsequent hospital readmissions.[5] The majority of complications after RC are minor (Clavien grade I–II), however from 13% to 22% of patients experience a major complication (Clavien grade III–V) (see Table 41.1). Patients who experience a complication tend to have longer hospital length of stay (LOS) and higher costs.[4,5,7,11]

The most commonly reported risk factor for a postoperative complication is patient comorbidity.[3,5,11,12,17,18] In a

Table 41.1 Summary of 90-Day Radical Cystectomy Complications Based on Institutional Cohorts Using Contemporary Reporting Methods

Complication Years	Shabsigh[5] 1995–2005	Takada[12] 1997–2010	Schiavina[11] 1995–2009	Novara[7] 2002–2006	Hautmann[3] 1986–2008
Number	1142	928	404	358	1013[c]
Overall	64%	68%	52%	49%	58%
Minor[a]	51%	51%	34%	36%	36%
Major[a]	13%	17%	17%	13%	22%
By organ system					
Gastrointestinal	29%	26%	15%	17%	15%
Infectious	25%	30%	11%	7%	24%
Wound	15%	21%	5%	7%	9%
Genitourinary	11%	15%	8%	7%	17%
Cardiac	11%	<1%	8%	8%	-
Pulmonary	9%	1%	6%	5%	-
Bleeding	9%	<1%	6%	16%	-
Thromboembolic	8%	<1%	4%	4%	-
Neurologi	5%	2%	3%	3%	-
Miscellaneous	3%	3%	9%	1%	-
Surgical	1%	<1%	1%	0%	-
Reoperation[b]	14%	11%	7%	10%	-
Return to OR	3%	9%	-	-	-
IR procedure	11%	3%	-	-	-
Mortality	3%	2%	5%	3%	2%

IR, interventional radiology; OR, operating room
[a]Minor complications considered Clavien grades I and II. Major complications considered Clavien grades III–V
[b]Includes return to the operating room and interventional radiology procedures
[c]Includes patients with orthotopic neobladders only

large retrospective study, patients with an American Society of Anesthesiologists (ASA) score of three or four had a 50% increased risk of complications (OR 1.5; 95% CI 1.04, 1.82; p = 0.02) on multivariate analysis.[5] A similar finding was reported by a large Japanese series.[12] Increasing age is also associated with the risk of any complication and severe complications.[3,12,17,18] One series noted a 40% increase in complications among patients over the age of 70.[12] Additional risk factors for complications include longer operating room time,[12] continent diversion,[5] female gender,[5] higher tumor stage,[3] more intraoperative blood loss,[5] and a greater body mass index (BMI).[19] Higher surgeon and hospital volume are associated with lower morbidity and mortality following RC.[4,17,27,28] Use of neoadjuvant chemotherapy does not appear to increase perioperative complications.[29,30]

Several preoperative interventions have been proposed to lessen the morbidity of major surgery, including smoking and alcohol cessation,[31,32] nutritional support,[33] shortened duration of fasting,[34] carbohydrate loading,[35] and exercise programs.[36] Future studies are required to better understand the impact of preoperative interventions, or "prehabilitation," on postoperative outcomes for RC patients.

Complications by Organ System

Postoperative complications can be broadly grouped into 11 different organ systems (see Table 41.1). The most common categories of complications are gastrointestinal, infectious, wound, and genitourinary.

GASTROINTESTINAL COMPLICATIONS

Gastrointestinal complications are among the most common postoperative complications, occurring in 15–29% of patients (see Table 41.1); they additionally are covered broadly in Chapter 11. The majority of gastrointestinal complications are attributed to ileus; however, small bowel obstruction, anastomotic bowel leak, gastrointestinal bleeding, and *Clostridium difficile* colitis (CDC) can also occur. Gastrointestinal complications in this setting are largely due to the urinary diversion, but can be partially attributed to the handling and mobilization of bowel during the cystectomy.

Ileus

Depending on the definition used, 7–23% of RC patients experience postoperative ileus.[3,5,11,12] Ileus is a functional small bowel obstruction due to impairment of peristalsis and is commonly defined by the absence of bowel function by postoperative day 5, nasogastric tube placement, or conversion to NPO status due to nausea, vomiting, or abdominal distention.[3,5] Ileus is the most common cause of prolonged LOS following RC.[37] Risk factors for ileus after RC include higher BMI, increasing age, longer operating time, and use of general anesthesia.[38] Ileus usually presents with abdominal distention in the absence of bowel function, but may progress to abdominal pain, nausea, and emesis.

Ileus is thought to occur due to an insult to small bowel innervation from irritation, inflammation, manipulation, or medication effects, and there are several proposed inciting factors.[39] Abdominal surgery, with manipulation of the bowel, is the most common cause of ileus. Several medications have also been implicated, particularly opioids and anticholinergics, as have metabolic abnormalities, including hypokalemia, hypocalcemia, hypomagnesemia, and hyponatremia.

The primary treatment of ileus is supportive, with intravenous hydration, correction of electrolyte abnormalities, and avoidance of offending medications. Nasogastric decompression is often indicated for patients with emesis or significant abdominal distention. Although widely recommended, there is no evidence that early and aggressive ambulation treats or prevents ileus. There are, however, several treatments that have been studied for the treatment or prevention of postoperative ileus.

Prokinetic agents are widely used to prevent and treat ileus, but there are relatively little data to support their effectiveness.[40] Most studies on prokinetic agents have been conducted following colorectal surgery, although their findings are likely generalizable to RC patients. Metoclopramide achieves prokinetic effects through its action on cholinergic and dopamine receptors in the upper gastrointestinal tract. In a small study of RC patients, metoclopramide was associated with less nausea and vomiting (3% vs 12%, p = 0.01) but no difference in return of bowel function, rate of ileus, or time to discharge.[41] Another study found that when combined with early nasogastric tube removal, metoclopramide is associated with a faster return of bowel function after RC.[42] Erythromycin is a macrolide antibiotic that has been used as a prokinetic given its effects on motilin receptors in the gastrointestinal tract. One small study randomized 22 RC patients to receive low-dose intravenous erythromycin or placebo starting on postoperative day 1 and found no difference in recovery of bowel function.[43] These results are in agreement with other randomized studies from the general surgery literature suggesting erythromycin has limited benefit to treat or prevent postoperative ileus.[40]

Alvimopan is a peripheral opioid μ-receptor antagonist that blocks the effect of opioids on the gastrointestinal tract. It is approved by the U.S. Food and Drug Administration (FDA) to accelerate gastrointestinal recovery following a bowel resection and primary anastomosis. A recent multicenter randomized study examined the use of alvimopan in RC patients to accelerate the return of gastrointestinal function and decrease LOS.[44] A total of 280 patients were randomized to receive alvimopan or placebo between 30 minutes and 5 hours before surgery and continued until the day of discharge or postoperative day 7. Patients receiving alvimopan recovered their gastrointestinal function 1 day earlier (day 5.5 vs 6.8, p < 0.0001), had a shorter LOS (7.4 vs 10 days, p < 0.01), and less postoperative ileus-related morbidity including use of nasogastric decompression and prolonged LOS. Alvimopan has a favorable safety profile and may be associated with lower hospital costs after RC.[45]

Methylnaltrexone is another opioid μ-receptor antagonist that is FDA approved to treat opioid-induced chronic constipation. Although methylnaltrexone has not been studied in RC patients, there have been two randomized controlled trials examining its use in treating postoperative ileus after colorectal surgery.[46] Each was a multi-institution trial that randomized patients to 12 or 24 mg of intravenous methylnaltrexone or placebo following segmental colectomy. With over 1000 patients randomized, neither study

demonstrated faster return of bowel function or time to hospital discharge in patients receiving methylnaltrexone. Ghrelin agonists,[47] cholinergic agents,[48] and even acupuncture[49] have been studied for reducing postoperative ileus; however, none have demonstrated success.

Because ileus is thought to occur from an imbalance of the sympathetic and parasympathetic innervation to the small bowel, the cholinesterase inhibitor neostigmine has shown benefit in treating postoperative ileus.[40] Some centers have routinely administered neostigmine after RC, although this medication has not specifically been studied in RC patients.[50] Due to the inhibitory effect of opioids on gastrointestinal motility, limiting the use of opioids for postoperative pain control has also been tested as a means of reducing postoperative ileus. Intravenous acetaminophen, epidural anesthesia, and nonsteroidal antiinflammatories, such as ketorolac, are all effective means of limiting opioid exposure and may help reduce ileus.[51–54]

Fluid overload may cause bowel wall edema and inhibit bowel function, and fluid restriction can result in faster recovery of bowel function.[55] Recently, 166 RC patients were randomized to receive usual versus restricted intraoperative hydration.[56] Patients in the restricted fluid cohort received significantly less intraoperative fluid (1.7 L vs 4.3 L, $p < 0.0001$) and had an 84% relative reduction in gastrointestinal complications (6% vs 37%, $p < 0.0001$), primarily due to a reduction of ileus (0% vs 10%) and constipation (2% vs 22%).

Based on observations that chewing has a stimulatory effect on bowel motility, gum chewing has been studied as a treatment of postoperative ileus. Kouba et al. compared 51 RC patients who were instructed to chew gum starting on postoperative day 1 to 51 historic RC patients who did not chew gum.[57] Patients who chewed gum had slightly faster time to flatus (2.4 vs 2.9 days, $p < 0.001$) and to first bowel movement (3.2 vs 3.9 days, $p < 0.001$). Coffee also has stimulatory effects on the gastrointestinal tract, and another study randomized 80 patients to drink coffee or water after colectomy.[58] Patients who drank coffee had a shorter time to first bowel movement (60 vs 74 hours, $p = 0.006$), but there was no difference in LOS or postoperative complications.

Routine gastric or nasogastric decompression was often used following RC in an effort to decrease gastrointestinal complications. A large retrospective study compared 221 RC patients that had a prophylactic postoperative nasogastric tube to 199 RC patients who did not.[59] There was no difference in time to first bowel movement or gastrointestinal complications, although patients with nasogastric tubes tended to have longer LOS. Nearly 20% of the patients without a prophylactic nasogastric tube eventually required one, and 15% of patients who had their prophylactic nasogastric tube removed needed reinsertion. These observations are supported by a large meta-analysis and Cochrane review, each of which failed to demonstrate the benefit of routine prophylactic nasogastric decompression following elective laparotomy, and instead found an increased risk of pulmonary complications.[60,61]

In another effort to avoid gastrointestinal complications, RC patients are often kept without food or liquid as bowel function recovers. Given the catabolic effects of major surgery, some centers have used parenteral nutritional support prior to the return of bowel function. Roth et al. randomized 157 RC patients to postoperative parenteral nutrition for 5 days, beginning on postoperative day 1, or usual care with early enteral feeding.[62] Patients receiving parenteral nutrition had more complications (69% vs 49%, $p = 0.013$), including a higher rate of infectious complications (32% vs 11%, $p = 0.001$), but no difference in recovery of gastrointestinal function. Current guidelines from the European Society for Clinical Nutrition and Metabolism state that parenteral nutrition is beneficial in undernourished patients when enteral nutrition is not feasible or not tolerated, or in patients who have impaired gastrointestinal function and an inability to tolerate enteral feeds for at least 7 days.[63]

Recent evidence supports the safety of early enteral feeding following gastrointestinal surgery.[64] A retrospective study of RC patients found that early enteral feeding was associated with fewer postoperative complications and a shorter LOS when compared to parenteral nutrition and nothing by mouth.[65] A Cochrane review found that patients that had colorectal surgery who were fed within 24 hours did not have a higher risk of postoperative complications, including bowel leak, wound infection, and LOS, when compared to patients who were kept with no oral intake until the return of bowel function.[66] Therefore a strategy of early enteral feeding can provide needed nutrition and does not appear to be associated with a higher rate of complications.

Mechanical bowel preparations are often used prior to RC, with the intent of facilitating surgery by decreasing fecal load and reducing gastrointestinal and infection complications. Based on several meta-analyses in the colorectal literature, the use of mechanical bowel preparations has come into question as there is no evidence they reduce anastomotic leaks, wound infections, or gastrointestinal morbidity.[67,68] A retrospective study compared gastrointestinal and infectious complications between 105 RC patients who had a mechanical bowel preparation to 75 who did not.[69] There was no difference in postoperative *C. difficile* infection, wound infection, or severe abdominal or gastrointestinal complications. Another retrospective series compared 37 RC patients who had a mechanical bowel preparation to 33 who did not.[70] There were no differences in time to flatus, time to first bowel movement, LOS, or severe complications between the two groups. While a mechanical bowel preparation may be helpful when using a colonic segment for urinary diversion, it can safely be omitted for a diversion using ileum.

Some have hypothesized that gastrointestinal morbidity following RC may be due to the interaction between the bowel and deperitonealized pelvis, leading to bowel inflammation and adhesion formation. Roth et al. randomized 200 patients having RC and extended pelvic lymph node dissection (PLND) to readaptation of the peritoneum over the dorsolateral pelvic walls versus no readaptation.[71] Readaptation of the peritoneum was associated with faster return of bowel function, fewer complications, and less postoperative pain, but there was no difference in LOS. A follow-up study suggested better long-term bowel function in patients who had peritoneal readaptation.[72] The authors propose this as a safe, effective, and easy way to decrease postoperative gastrointestinal morbidity.

Standardized pathways and enhanced recovery protocols after RC have been employed for over 10 years in an effort

to reduce complications, accelerate the return of bowel function, and reduce LOS using evidence-based medicine.[37] The meaningful gains in postoperative recovery realized from these protocols are achieved by combining the modest benefits of multiple interventions.[73] In 2010 Pruthi et al. described their experience with a "fast track" program for RC that employed several evidence-based strategies, including immediate removal of nasogastric tubes, use of metoclopramide, minimization of narcotic analgesia, early enteral feeding, and use of chewing gum.[41] Although this was not a comparative study, 80% of fast track patients were discharged by postoperative day 5 and the average time to return of bowel function was 2.2 days. A German group randomized RC patients 2:1 to an enhanced recovery pathway (N = 62) and usual care (N = 39).[74] The enhanced recovery pathway included a limited bowel preparation, preoperative nutritional support, early enteral feeding, immediate nasogastric tube removal, early mobilization, and use of prokinetic agents. The enhanced recovery group had better quality of life, fewer inpatient complications, and decreased analgesic demand, but there were no differences in ileus or LOS. Finally, the University of Southern California group described their experience using an extended recovery protocol in 110 RC patients.[75] The extended recovery protocol included pre-, intra-, and postoperative interventions, such as patient education, absence of a bowel preparation, use of alvimopan and prokinetic agents, minimization of intravenous fluid and narcotic analgesia, no prophylactic nasogastric tube use, and early enteral feeding. Patients treated with this protocol had a median time to flatus and LOS of 2 and 4 days, respectively. Still, the 30-day complication rate was 65%, and 21% of patients were readmitted, generally due to dehydration or infection. When combined with surgical expertise, extended recovery programs may lessen gastrointestinal morbidity and reduce LOS; however, they do not appear to reduce overall complications or readmissions.

Small Bowel Obstruction

Ileus is the most common gastrointestinal complication, although approximately 7% of RC patients experience a small bowel obstruction.[5] Because both complications can present similarly, abdominal computed tomography (CT) with oral contrast is often helpful in diagnosing a bowel obstruction, with the characteristic finding of dilated bowel up to a transition point with distal compression. Most small bowel obstructions are the result of internal adhesions or bowel edema. Initial treatment for a small bowel obstruction includes supportive care with intravenous hydration and electrolyte replacement, nasogastric decompression, and bowel rest. While this may be effective at resolving the obstruction, it is critical to monitor for signs of bowel ischemia or perforation through vital signs, serial exams, and periodic blood work, with particular attention being paid to the white blood cell count. If the obstruction does not resolve with conservative measures, abdominal exploration may be required.

Clostridium difficile Colitis

CDC is caused by the gram-positive spore-forming bacterium *C. difficile*. CDC has historically been a rare complication following RC that occurred in fewer than 3% of patients.[5,12,76,77] However, a recent study observed an 8.8% prevalence of CDC within 90 days of RC, with an increase over time.[78] This condition is associated with prolonged LOS, patient morbidity, and increased costs and causes up to 10% of RC readmissions.[77,78]

The diagnosis of CDC is made in the presence of symptoms of colitis, such as diarrhea, abdominal pain, and leukocytosis, and a positive fecal *C. difficile* toxin or culture. Rarely, patients will develop severe manifestations of CDC such as pseudomembranous colitis or toxic megacolon.

The primary risk factor for CDC is exposure to antibiotics that are thought to disrupt normal bowel flora, particularly fluoroquinolones, clindamycin, and broad-spectrum penicillin and cephalosporins.[79] The duration of antibiotic exposure is also an important risk factor. A recent study found that RC patients were on average treated with 10 days of perioperative antibiotics, and use of an extended duration of antibiotics was associated with a 60% higher risk of CDC.[76] Another study found that patients who were treated with perioperative antibiotics for at least 7 days had double the odds of CDC.[78] Other risk factors for CDC include older patient age, immunosuppression, chronic antacid therapy, and longer LOS.[80]

The two most important methods to avoid *C. difficile* transmission are minimization of unnecessary antibiotics and meticulous hand hygiene with removal of bacterial spores using soap and water. Current guidelines recommend treating CDC according to disease severity.[80] Consideration should be made to discontinuing offending antibiotics and consulting with an infectious disease specialist. Patients with mild-to-moderate infection should be treated with oral metronidazole 500 mg three times daily for 10–14 days, whereas those with a severe infection should be treated with oral vancomycin 125 mg four times daily for 10–14 days. Complicated cases may require higher doses of oral vancomycin, intravenous metronidazole, vancomycin enemas, or other antibiotics. Patients who develop a severe infection or toxic megacolon may require a colectomy.

Anastomotic Leak

A bowel anastomotic leak occurs in less than 2% of RC patients.[5,7,8,12] The severity of a bowel leak is variable, but has a risk of causing significant morbidity and mortality.[3,81] There are several risk factors for an anastomotic leak including active smoking, obesity, and immunosuppression.[82] Meticulous surgical technique with creation of a tension-free and well-vascularized anastomosis is necessary to avoid leaks. An anastomotic leak is often diagnosed clinically with signs of systemic infection or peritonitis on physical examination. A radiologic diagnosis can be made by visualizing leakage of oral contrast on a CT scan. Some leaks may be managed conservatively with bowel rest and antibiotics; however, many patients require exploration. A general surgery consult is often warranted.

Acute Colonic Pseudo-obstruction

Finally, acute colonic pseudo-obstruction (Ogilvie's syndrome) is a functional obstruction of the colon due to bowel paralysis, likely due to an imbalance of autonomic innervation.[83] It is a rare complication after RC, and the exact causes are unknown. On imaging, many patients with acute colonic pseudo-obstruction have large bowel dilation to a transition point in the descending colon. Most cases improve with conservative measures, including nasogastric

and rectal decompression, correction of electrolyte imbalances, and avoidance of constipating medications, although there is a small risk of colonic perforation. Patients who fail 2–3 days of conservative treatment as well as those with significant cecal dilation (>12 cm) or long-standing obstruction (>3 days) may require more aggressive treatments. Because acute colonic pseudo-obstruction is likely due to a deficit of parasympathetic innervation, low-dose (2 mg) neostigmine is an effective treatment.[84] Neostigmine causes systemic manifestations of excess cholinergic supply, such as salivation, sweating, bronchospasm, and bradycardia, necessitating cardiac monitoring. For those who fail neostigmine or for whom it is contraindicated, endoscopic decompression may be indicated.[83,85] Patients with colonic ischemia or perforation require colectomy.

INFECTIOUS COMPLICATIONS

Infections are also very common following RC and occur in up to 30% of patients (see Table 41.1). The prevention and management of infections are reported in detail in Chapter 7. The majority of infections occur within the urinary tract, although RC patients are also at risk for intraabdominal infections and abscesses, often from enteric organisms. Symptoms of infection range from a low-grade fever or mild leukocytosis to severe sepsis. Surgeons must be vigilant in monitoring for infectious symptoms and have a low threshold for initiating a complete infectious workup, including blood and urine cultures, chest imaging, and, when indicated, abdominal imaging. Initial treatment includes fluid administration and broad-spectrum antibiotics, which should ultimately be narrowed to culture data. Early source control is critical, including drainage of intraabdominal collections or relief of urinary obstruction.

Although there have been no randomized trials to examine the effectiveness of prophylactic antibiotics to prevent infections in RC patients, both the American Urological Association and European Association of Urology recommend administration of prophylactic antibiotics within 1 hour of incision and not continued for longer than 24 hours postoperatively.[86,87] First-line antimicrobial prophylaxis includes either a second- (i.e., cefazolin, cefoxitin, cefuroxime) or third- (i.e., ceftriaxone, ceftazidime, cefotaxime) generation cephalosporin, or aztreonam plus metronidazole or clindamycin.[86] The choice of antibiotics may also be guided by previous culture data and the local antibiogram.

GENITOURINARY COMPLICATIONS

Genitourinary complications occur in 8–15% of patients and are typically related to the urinary diversion.[5,11,12] Urinary complications related to urinary diversion are covered in more detail in Chapters 13, 45, 46, and 47. The majority of early diversion-related complications are ureteral obstruction and urinary leak.

Ureteral Obstruction

Early ureteral obstruction occurs in 4–10% of RC patients and can cause flank pain, infection, and renal insufficiency.[5,12] Such symptoms should prompt upper tract imaging. The obstruction is most often at the site of the ureterointestinal anastomosis and can generally be prevented by meticulous surgical technique. Treatment requires relief of the obstruction, usually with a percutaneous nephrostomy tube. While not used by all surgeons, ureteral stents placed at the time of the ureterointestinal anastomosis may facilitate healing, avoid anastomotic leaks, and hasten recovery, although there is no evidence they reduce strictures or early obstruction.[88,89]

Urine Leak

A urine leak occurs in up to 4% of RC patients and may originate from the ureteral anastomosis, the proximal end of an ileal conduit, the sutured wall of an orthotopic neobladder or continent cutaneous diversion, or the urethroneovesical anastomosis of an orthotopic neobladder.[5,12] Early leaks may be detected through high intraperitoneal drain output with elevated fluid creatinine that is consistent with urine. Undrained leakage of urine into the peritoneal cavity can result in chemical peritonitis, ileus, and abdominal distention. Often the serum creatinine will be elevated as intraperitoneal urine is absorbed. Treatment of a urine leak requires urinary tract drainage and decompression, using percutaneous drains, nephrostomy tubes, or Foley catheters. Many leaks will resolve with conservative management alone.

There are many uncommon diversion-related early complications such as stomal necrosis, stomal retraction, and neobladder perforation. In general, complications such as these are managed nonoperatively with catheter or nephrostomy drainage, with a potential for a delayed repair.

WOUND COMPLICATIONS

Wound complications occur in up to 21% of patients, the majority of which are infections.[5,12] Complications related to the wound are covered in more detail in Chapter 9.

Wound Infection

Radical cystectomy and urinary diversion with controlled entry into the gastrointestinal tract is considered a clean-contaminated procedure with an estimated 4–10% wound infection risk.[87] With spillage of gastrointestinal contents, the procedure becomes contaminated and the risk increases to 10–15%. Overall, 9–19% of RC patients experience a postoperative wound infection.[5,12] Symptoms of a wound infection are pain, redness, fevers, leukocytosis, and purulent drainage, although early infections can be asymptomatic. Risk factors for wound infection include patient comorbidity, longer procedure duration, open surgery, wound classification, malignancy, malnutrition, diabetes, smoking, blood transfusion, and obesity.[90–93]

Methods to reduce wound infections include perioperative antibiotic prophylaxis, skin sterilization, and abdominal closure techniques, such as incisional lavage, tissue approximation to eliminate dead space, and subcutaneous drains to minimize fluid accumulation.[94] Skin preparations used for preoperative skin sterilization are based either on iodine or chlorhexidine. A recent randomized trial observed a 40% reduction in surgical site infections after clean-contaminated surgery in patients who had a chlorhexidine-alcohol skin preparation, compared to patients with a povidone-iodine skin preparation.[91] Prevention of intraoperative hypothermia and postoperative

hyperglycemia, both risk factors for wound infections, may also reduce surgical site infections.[95,96] It is unclear if hair removal is associated with a decreased risk of surgical site infections; however, electronic clippers should be used if hair removal is performed.[97] Mechanical bowel preparation is not associated with a reduction in wound infections.[67,70]

Several groups have implemented perioperative care bundles to successfully reduce surgical site infections.[98] These bundles include several evidence-based practices such as antibiotic prophylaxis, glycemic control, normothermia, and appropriate hair removal, as well as items implemented during abdominal closure, including a change in gloves and gowns, wound lavage, and using a clean set of instruments.[98]

The immediate treatment of a wound infection is to open, clean, and pack the wound and administer antibiotics. While many patients develop infections from gram-positive organisms, gram-negative infections can also occur, necessitating wound culture and initial use of broad-spectrum antibiotics. Wound packing will be successful in treating the majority of infections, but requires prolonged local wound care and healing by secondary intention.

Skin Separation and Fascial Dehiscence

Other wound complications include seromas, skin separation, and fascial dehiscence. Skin separation is treated with local wound care, including packing or a negative pressure dressing. In the absence of necrotic tissue and infection, healing by secondary intention will occur over the course of several weeks, depending on the size of the wound.

Fascial dehiscence is rare in many series (<1%), although a recent study observed a 3.2% prevalence following RC.[5,7,12,99] In this study, the dehiscence occurred at a median of 11 days postoperatively and all patients who had a dehiscence also had a wound infection.[99] Predictors of dehiscence included obesity, chronic obstructive pulmonary disease (COPD), and wound infection. Fascial dehiscence often requires reoperation and abdominal wall closure given the risk of evisceration. While patient factors may impact the development of fascial dehiscence, it is strongly related to technical factors during fascial closure.

There are several ways to close the abdominal fascia, including use of running or interrupted sutures and choice of permanent, braided absorbable and monofilament absorbable sutures. The fascia must be closed in a tension-free manner with approximation of healthy tissue. A recent trial randomized patients to midline abdominal closure with interrupted braided absorbable suture or a continuous absorbable monofilament suture with a suture:wound length ratio of 4 : 1.[100] There was no difference in incisional hernia rates at 1 year or wound complications, including fascial dehiscence. However, a meta-analysis observed lower rates of hernias with closure using a continuous slowly absorbable suture as compared to an interrupted technique.[101] Specifically regarding the technique of midline closure using a continuous monofilament absorbable suture, a recent randomized trial demonstrated that smaller fascial bites (5 mm every 5 mm) were associated with a significantly lower risk of incisional hernia at 1 year (13% vs 21%; OR 0.52; 95% CI 0.31–0.87; p = 0.0131) than larger tissue bites (1 cm every 1 cm); however, there was no difference in fascial dehiscence or wound complications.[102] In our opinion, high-risk patients especially may benefit from prophylactic external retention sutures for 4–6 weeks.

BLEEDING COMPLICATIONS

Intraoperative blood loss during RC ranges from 600 mL to 1300 mL and 29–82% require a transfusion of blood products.[7–12,19] Risk factors for blood transfusion include female gender,[16] higher BMI,[103,104] lower preoperative hemoglobin,[105] and higher tumor stage.[105] Blood transfusions carry risks of transfusion reactions and transmission of infectious diseases. Patients who receive transfusions after RC may also have an increased risk of postoperative complications,[106] disease recurrence, and mortality.[105,107] The majority of bleeding during RC occurs along the lateral pedicles or dorsal venous complex. In women, the paravaginal tissues are highly vascular and can also be a source of bleeding. Early vascular control is critical to avoid excess bleeding.

There are several methods to control the vascular pedicle, including clips and ties, staplers, and energy devices. A randomized trial demonstrated less blood loss and fewer blood transfusions during RC when a stapler was used to ligate the vascular pedicles compared to conventional techniques.[108] More recently, the same group randomized RC patients to tissue ligation by stapler or the LigaSure, an electrothermal bipolar tissue ligation device.[109] There were no differences in blood loss, operative time, or transfusion requirements between the two groups; however, the device-associated cost was lower with the LigaSure group.

There are a variety of topical hemostatic agents that can be helpful adjuncts to control venous bleeding.[110] The use of topical hemostatic products is common during RC.[111]

Strategies to reduce intraoperative volume administration have shown promise in reducing intraoperative blood loss. In an effort to reduce perioperative blood transfusions, the Bern group randomized 166 RC patients to restricted intraoperative hydration versus usual care.[112] The restricted hydration group had significantly less intraoperative blood loss (800 mL vs 1200 mL, p < 0.0001) and required fewer blood transfusions (33% vs 60%, p = 0.0006). This effect may have occurred through a reduction in pelvic venous pressure.[113] Intraoperative cell salvage collects and reinfuses the patient's own red blood cells during surgery and has successfully been used during RC.[114]

For significant pelvic bleeding that is difficult to control or in a patient with coagulopathy, the pelvis can be packed while the patient is resuscitated and stabilized. In some instances, the pelvis can be packed and the abdomen temporarily closed with return to the operating room at a later time. In these rare circumstances, the urine can be diverted with externalized ureteral catheters.

Ultimately, prevention of bleeding requires a knowledge of vascular anatomy, along with variations in anatomy, and experience in properly achieving exposure during vascular control, regardless of pelvic anatomy. Most often, bleeding occurs when the anatomy of the pelvis is distorted due to anatomic variation, tumor size and extent, previous surgery, or radiation. In these cases, patience of the surgeon and adherence to anatomic principles are critical in avoiding uncontrolled bleeding upon division of the bladder pedicles, mobilization of the pelvic floor, or division of the dorsal vein.

THROMBOEMBOLIC COMPLICATIONS

Venous thromboembolism (VTE) occurs in 1–8% of RC patients within 90 days of surgery.[5,7,11,12] The majority of VTE events are deep venous thrombosis (DVT), although pulmonary emboli (PE) occur in up to 3% of patients and represent a significant cause of postoperative mortality.[5,81,115] There are several risk factors for VTE including older age, higher BMI, personal or family history of VTE, malignancy, smoking, increased comorbidity, and immobility.[116–118] Patients having a long open abdominal or pelvic operation have a particularly high risk of VTE.

The use of prophylactic low-dose unfractionated heparin (LDUH) and low-molecular-weight heparin (LMWH) is associated with a reduced risk of VTEs, including fatal PE and death, but an increase in nonfatal bleeding.[117] LDUH and LMWH are equally effective at VTE prophylaxis. Mechanical VTE prophylaxis, with sequential compression devices or elastic stockings, has also been shown to reduce DVTs, but there is no evidence it reduces the risk of fatal PE or death.[117] When compared to pharmacologic prophylaxis alone, mechanical prophylaxis is associated with an 80% increased risk of DVT, but a 60% decreased risk of bleeding.[117] The combination of pharmacologic and mechanical prophylaxis may further reduce VTE risk compared to pharmacologic prophylaxis alone.

Current guidelines from the American College of Chest Physicians and the American Urological Association recommend individualized assessment of VTE risk for surgical patients (Table 41.2).[117,118] RC patients are generally elderly, have a malignancy, require a prolonged open abdominal operation, and have restricted mobility during their recovery, putting them in the highest risk category for VTE.[117] These patients should be treated with prophylactic LMWH or LDUH beginning at the time of surgery and continuing throughout their hospital stay, unless the risk of bleeding is excessive. Concurrent use of mechanical prophylaxis and early ambulation is also recommended.

A recent study described the prevalence and timing of VTE in over 1300 RC patients.[119] The rate of VTE within 30 days of surgery was 6% and over 50% of VTEs occurred after hospital discharge. A similarly high rate of post-discharge VTE was reported using a large institutional cohort.[120] An increased risk of DVT for up to 12 weeks has led some to recommend long-term use of chemoprophylaxis.[117] Following abdominal or pelvic cancer surgery, use of prophylactic LMWH for 4-weeks is associated with at least a 50% reduction in DVTs compared to a 1-week course.[117,121] The American College of Chest Physicians currently recommends an extended duration of prophylaxis with LMWH for high-risk patients.[117] Preventive strategies for VTE are additionally discussed in detail in Chapter 4.

Table 41.2 Preoperative Venous Thromboembolism Risk Stratification and Treatment Recommendations for Patients Having Gastrointestinal, Urologic, Vascular, Breast, and Thyroid Procedures

Risk Category	Risk Score[a]	VTE Risk in Absence of Prophylaxis	Recommended Prophylaxis
Very low	0	<0.5%	Early ambulation only
Low	1–2	1.5%	Mechanical prophylaxis, preferably with sequential compression devices
Moderate	3–4	3.0%	■ Pharmacologic[b] OR mechanical prophylaxis, preferably with sequential compression devices OR ■ Mechanical prophylaxis if bleeding risk is high, preferably with sequential compression devices
High	≥5	6.0%	■ Pharmacologic[b] AND mechanical prophylaxis OR ■ Mechanical prophylaxis if bleeding risk is high, preferably with sequential compression devices[c]
High-risk cancer surgery			■ Pharmacologic[b] AND mechanical prophylaxis AND extended duration LMWH post-discharge OR ■ Mechanical prophylaxis if bleeding risk is high, preferably with sequential compression devices[c]

[a]Caprini risk score:
1 point: age 41–60, minor surgery, BMI >25, swollen legs, varicose veins, pregnancy or postpartum (<1 mo), history of unexplained or recurrent spontaneous abortion, oral contraceptives or hormone replacement, sepsis (<1 mo), severe lung disease including pneumonia (<1 mo), abnormal pulmonary function, acute myocardial infarction, congestive heart failure (<1 mo), inflammatory bowel disease, medical patient at bed rest
2 points: age 61–74, arthroscopic surgery, major open surgery (>45 min), laparoscopic surgery (>45 min), malignancy, confined to bed >72 hrs, immobilizing cast (<1 mo), central venous access
3 points: age ≥75, history of VTE, family history of VTE, factor V Leiden, prothrombin 20210A, lupus anticoagulant, anticardiolipin antibodies, elevated serum homocysteine, heparin-induced thrombocytopenia, other congenital or acquired thrombophilia
5 points: stroke (<1 mo), elective arthroplasty, hip, pelvis, or leg fracture (<1 mo), acute spinal cord injury (<1 mo)
[b]LDUH and LMWH both acceptable for pharmacologic prophylaxis
[c]LMWH or LDUH can be added once bleeding risk diminishes
(Adapted from Gould MK, Garcia DA, Wren SM, et al. Prevention of VTE in nonorthopedic surgical patients: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest. 2012;141:e227S-77S.)

CARDIAC COMPLICATIONS

Radical cystectomy is considered to have an elevated risk of postoperative major cardiac events,[122] and upward of 11% of RC patients experience a postoperative cardiac complication.[123] Cardiac complications can be associated with significant morbidity and mortality.[81,124] Preoperative cardiac assessment and perioperative cardiac management are reviewed in detail in Chapter 3. Risk factors for perioperative cardiac complications include high-risk coronary artery disease, stroke within 3 months of surgery, coronary artery stent placement within 6 months of surgery, renal insufficiency, diabetes, congestive heart failure, atrial fibrillation, peripheral vascular disease, hypertension, severe aortic stenosis, male sex, and age over 75.[124] The

most common cardiac complication is an arrhythmia, of which atrial fibrillation is most frequent.[123] Patients with a known cardiovascular disease, or risk factors for cardiovascular disease, are at high risk for a postoperative cardiac complication and should have a full preoperative cardiac risk assessment.[123,124]

Patients with a history of coronary disease, and particularly those with coronary stents, should be maintained on low-dose aspirin unless the bleeding risk is unacceptably high.[122] The decision to continue perioperative antiplatelet therapy for patients with cardio- or cerebrovascular disease should be made in conjunction with the treating internist, anesthesiologist, and urologist.[122,125] Patients who are taking beta-blockers and statins before surgery should continue these medications perioperatively.[122] Other factors that may reduce the risk of cardiac events include pain control, avoidance of hypotension, and restricted use of intravenous fluids.[56]

Although anemia may further impair myocardial oxygen delivery to patients with cardiovascular disease, there is no apparent benefit to a liberal transfusion threshold for high-risk patients having noncardiac surgery.[126] Further, blood transfusions are associated with an increased risk of infectious complications and adverse survival outcomes after RC, supporting more conservative transfusion thresholds.[107,127] Current recommendations call for a restrictive transfusion strategy in asymptomatic patients with a history of cardiovascular disease and consideration of transfusion for a hemoglobin <8 g/dL.[122]

PULMONARY COMPLICATIONS

Pulmonary complications occur in up to 9% of patients following RC.[5] The most common complications are pneumonia and respiratory distress, but others include respiratory failure requiring prolonged intubation or reintubation, pleural effusion, and pneumothorax.[5,11,12] There are several risk factors for pulmonary complications after abdominal surgery including increased patient comorbidity, dependent functional status, COPD, obstructive sleep apnea (OSA), smoking, low albumin, and advanced age.[128] Additional procedural-related risk factors include prolonged operating time, general anesthesia, and prolonged LOS.

Patients with known or suspected pulmonary disease may require preoperative pulmonary evaluation and optimization of pulmonary function. Pulmonary function testing can identify patients who are at increased risk for postoperative pulmonary complications and help guide intra- and postoperative management.[128] Preoperative pulmonary optimization includes smoking cessation and alcohol abstinence, as well as treatment of underlying airway obstruction and respiratory infection.[129] Preoperative pulmonary assessment and perioperative management of specific pulmonary complications are reviewed in detail in Chapter 2.

NEUROLOGIC COMPLICATIONS

Neurologic complications occur in less than 5% of RC patients. Peripheral neuropathy and delirium are the most common neurologic complications; however, stroke and seizure have also been reported.[5,7,11]

Delirium

Delirium is significantly more common among elderly hospitalized patients. Risk factors for postoperative delirium include preexisting cognitive or psychiatric disorder, increased patient comorbidity, poor functional status, older age, and polypharmacy, particularly with psychotropic medications and anticholinergics.[130] In a prospective study of 49 elderly patients having RC, nearly 30% experienced postoperative delirium, lasting an average of about 2 days and typically occurring early in the postoperative course.[131] Increased age was associated with an increased risk of delirium, and patients who experienced delirium had higher odds of being readmitted. Most patients developed an acute change in mental status with inattention and disorganized thinking. Patients at risk for delirium should have regular mental status assessments and should not be given benzodiazepines or anticholinergics.

Nerve Injury

Pelvic nerve injury can occur during RC or PLND, as several nerves that provide motor and sensory innervation to the lower extremities are intimately involved with the pelvic vasculature and lymphatic basin. The obturator nerve (L2–L4) traverses the obturator fossa beneath the external iliac vein. The obturator nerve provides motor innervation to the inner thigh and allows for hip adduction. The obturator nerve and vessels are skeletonized during removal of the obturator lymph node packet, and injury can occur secondary to cautery, excess traction, or accidental laceration. The deficit from an obturator nerve injury is inability to adduct the hip and a small area of anesthesia on the medial aspect of the thigh. Problems with hip adduction can cause difficulty walking and driving. Treatment primarily includes postoperative physical therapy, although some have attempted immediate primary reanastomosis or placement of a nerve graft with promising results.[132,133]

The genitofemoral nerve (L1–L2) courses over the psoas and functions as the lateral border of a PLND. This nerve provides sensation to a small area of skin overlying the femoral triangle as well as the scrotum in men and labia and mons pubis in women. It is a relatively thin nerve that can easily be injured or removed with the external iliac lymph node packet if not carefully identified. If injured due to excess traction, sensation may return over the course of several months.[134]

Finally, the femoral nerve (L2–L4) provides motor function to the quadriceps and much of the sensation to the anterior thigh and medial lower leg. It runs lateral to the psoas muscle and beneath the inguinal ligament. Although not typically visualized during RC, the femoral nerve can be compressed due to lateral traction on the psoas by self-retaining retractors or stretched during lithotomy positioning.[135] A femoral nerve injury can result in weakness of hip flexion, lower leg extension, and variable sensory deficits. Injury is best avoided through careful placement of self-retaining retractors and avoidance of exaggerated hip flexion, abduction, and external rotation in lithotomy. Depending on the mechanism of injury, use of early physical therapy to prevent muscle atrophy is often effective, with return of nerve function in many patients.[135]

Nerve injuries can be prevented by careful exposure, knowledge of anatomic landmarks, and control of hemostasis. Stretch injuries can recover over the course of several months. Nerve injuries that have associated motor deficits are best treated with early physical therapy.

INTRAOPERATIVE COMPLICATIONS

At high-volume centers, less than 1% of patients experience an intraoperative complication.[5] Intraoperative complications that can occur during RC include injury to the bowel or rectum, and major blood vessels or nerves. Using a large population-based dataset, approximately 3% of RC cases were complicated by an accidental puncture or laceration to an adjacent organ, and this was associated with higher inpatient mortality, LOS, and cost.[77] Rectal injuries are uncommon during RC, but are more likely in patients with prior pelvic radiation.[136] Small rectal injuries with minimal fecal contamination can be closed in several layers and covered with omental or peritoneal tissue flaps. Tissue interposition is particularly important to prevent fistulization for patients having an orthotopic neobladder. Some rectal injuries are better managed with primary closure and fecal diversion in consultation with a general surgeon. Retained foreign objects following RC are rare, occurring in less than 0.1% of cases.[137] Any urologist who performs RC must be aware of these potential intraoperative complications, understand how to manage them, and know when consultation with other surgical specialists is required.

Reoperation

Secondary interventions are not uncommon, as between 2% and 14% of patients require a reoperation or interventional procedure in the early postoperative period.[5,7,8,12,19] In a multi-institutional report from Sweden, 13% of patients required reoperation following RC.[8] There were 12 indications for reoperation, the most common of which were wound dehiscence (5%), wound infection (2%), and ileus (2%). An Italian series reported a 7% reintervention rate, with wound dehiscence and bowel obstruction the two most common indications for a return to the operating room.[7] A retrospective report from Greece reported a 9% rate of abdominal exploration within 30 days of RC.[138] Among 14 (3%) patients who were explored for bowel obstruction or ileus, approximately half had bowel adhesions and half had a problem with the bowel anastomosis. Only one patient (0.2%) was found to have an internal hernia.

Up to 11% of patients require an interventional radiology procedure after RC, nearly half of which occur following hospital discharge.[5] Most interventional radiology procedures are for drainage of intraabdominal abscesses or lymphoceles, or percutaneous nephrostomy placement for urinary leak or obstruction.

Readmission

Nearly one-third of patients will present to the emergency room and 19–27% require readmission within 90 days of RC.[5,7,22] Most readmissions occur within the first several weeks, although up to 11% of patients are readmitted between 31 and 90 days postoperatively.[15,139] Median LOS for readmitted patients is approximately 3–7 days.[15,139] The most common causes of readmission are ileus, pyelonephritis, urinary tract infection, urinary obstruction, and failure to thrive.[15,22,139] Risk factors for readmission include a higher number of medical comorbidities, postoperative complications, female gender, and discharge to a nursing facility.[15,22,139] Understanding which patients are at risk for readmission may impact the timing and disposition of initial hospital discharge. High-risk patients may require closer outpatient monitoring in the early postoperative period, home nursing visits, or a temporary stay in a rehabilitation hospital.

Complex operations such as RC are becoming more centralized to high-volume centers, thus patients will be increasingly likely to present to local hospitals for management of postoperative complications. Patients admitted to a different hospital than where their surgery was performed are at increased risk for postoperative mortality, in part due to care fragmentation.[140–143] Surgeons who perform RC at tertiary referral centers must work to communicate with patients while at home, identify complications early, and make every effort to admit patients to the index hospital when admission is indicated. Furthermore, it is important for surgeons to understand what resources are available to patients locally and establish a network of trusted providers who can treat or admit patients who are unable to travel to the index hospital.

Mortality

The risk of inpatient mortality after RC may be as high as 2%; however, this increases to at least 9% within 90 days of surgery.[17,21] The majority of deaths occur after hospital discharge.[5] Most deaths are attributed to cardiovascular complications, including myocardial infarction and arrhythmia, or sepsis and multiorgan system failure.[3,7,11,12,81] Most RC patients who die of sepsis have a urinary source or bowel leak.[3,7]

Several models have been created to predict the risk of postoperative mortality.[20,21,144] Using a population-level dataset, 1.1% and 3.9% of RC patients died within 30 and 90 days, respectively.[20] Older age, more advanced tumor stage, and nonurothelial histology predicted an increased risk of 90-day mortality. Patients at highest risk had an estimated 25% risk of mortality. In another population-level study of elderly RC patients, 90-day mortality was over 10% and the risk increased with older age, multiple comorbidities, more advanced stage, lower socioeconomic status, and unmarried status.[23] Patients over 80 with advanced disease and several comorbidities had an estimated 90-day mortality risk of nearly 25%.

Similar efforts have been made using institutional datasets. In one series of over 1000 RC patients treated at a high-volume center, 90-day mortality was 2.8%.[144] Older age, particularly over 70, and a Charlson comorbidity index over two were independently associated with mortality. The highest-risk group had an approximately 6% risk of death in 90 days. Using a multi-institutional cohort of RC patients, a nomogram was created to estimate 90-day mortality.[21] Nine percent of patients died within 90 days, and older age, higher ASA score, lower hospital volume, and metastatic

disease were all associated with a higher risk of 90-day mortality.

Patients who have signs of preoperative malnourishment are also at increased risk for postoperative mortality. Among 538 RC patients, nearly 20% had evidence of a preoperative nutritional deficiency, defined by low albumin, low BMI, and at least a 5% unintentional weight loss.[145] Patients with a nutritional deficiency had a nearly threefold increased risk of 90-day mortality on multivariate analysis (17% vs 5%), although low albumin alone may be the most important predictor.

An inverse relationship between hospital volume and postoperative mortality for RC has been well described.[27] The exact reason for this association is unclear, but may be related to underlying structural or process-related institutional factors.[146,147] High-volume centers may also be more prepared to manage potentially life-threatening postoperative complications.[14]

SPECIAL POPULATIONS

Elderly

Approximately 25% of RC patients are over the age of 75.[5,8] Previous studies have identified older age as an independent risk factor for postoperative complications[3,5,8,12,17,18] and mortality.[148] As a result, RC may be underutilized in elderly patients.[149] However, several institutional studies have specifically examined postoperative outcomes in elderly patients and suggested that elderly patients can do well after RC.

In a large retrospective cohort study, approximately 35% of RC patients were older than 70 and 5% were older than 80.[150] There was no significant difference in perioperative mortality according to age; however, older patients had higher rates of complications within 90 days and a slightly longer LOS. There was no adjustment for comorbidity status, but the authors suggested that properly selected elderly patients are good candidates for RC. A large German RC series described differences in complication rates between patients over and under age 70.[151] Patients over the age of 70 were more likely to have comorbid conditions, but were also at higher risk for postoperative complications after adjusting for comorbidity status.

A recent series described postoperative complications between RC patients younger (N = 1025) and older (N = 117) than 80 years.[152] Older patients had more comorbidities and were less likely to have continent diversions and PLND. Although older patients were more likely to require intensive care unit admission, had a slightly longer LOS, and higher 90-day mortality rate (2.7% vs 6.8%), they had similar risks of minor (55% vs 51%) and major (17% vs 13%) complications compared to younger patients. Elderly patients were, however, more likely to experience neurologic and cardiac complications.[152] After adjusting for preoperative characteristics, there was no increased risk of complications with age over 65.

While elderly patients may have similar risks of complications when treated at high-volume centers, they often require a unique preoperative evaluation. In addition to a thorough history and physical, with particular attention to cardiac and pulmonary risk factors, a preoperative geriatric risk assessment includes evaluation of cognitive function, alcohol and substance use, functional status, nutritional assessment, and frailty.[130,153] Frailty, defined by the presence of shrinking and weight loss, poor endurance or exhaustion, weakness, slow walking speed, and low physical activity level, is more common in elderly patients.[153] Frail patients are at particular risk for postoperative complications.[154] Older patients are also more likely to be dependent and sarcopenic, which are each associated with higher risks of morbidity and mortality.[153,155,156] Preoperative consultation with a geriatrician may help identify high-risk patients and assist with postoperative management.

Following Radiation Therapy

Radiation therapy for pelvic malignancies, including bladder, prostate, colorectal, and gynecologic, can cause significant tissue changes in and around the targeted area, such as obliteration of anatomic planes and a desmoplastic reaction. Radiation can also alter tissue vascularity and impair normal healing. Because of these effects, RC patients with a history of pelvic radiation were historically observed to have very high perioperative morbidity.[157]

Following radiation, RC generally takes longer and may be associated with more postoperative complications, including reoperation and readmission.[158] A series of 148 patients had RC following high dose pelvic radiation therapy, and nearly 80% of patients experienced a complication within the first 90 days, including a 32% high-grade complication and a 6% mortality rate.[159] Although this study was noncomparative, the authors suggested the complication rate in this population was higher than in other contemporary RC series. However, a large retrospective study compared 426 RC patients without to 420 patients with prior pelvic radiation and found no significant differences between postoperative mortality or complications.[157]

Up to 30% of patients with bladder cancer who elect bladder-sparing treatments that include external beam radiation therapy will require a salvage RC.[160] Among 91 patients who failed bladder-sparing multimodal therapy and required salvage RC, 69% experienced a complication within 90 days, including 16% who experienced a major complication.[160] The risk of postoperative complications appeared to decrease for patients treated in more recent years. However, few patients had PLND and nearly all had an incontinent diversion, suggesting PLND and continent diversion are more difficult after radiation.

Although the literature does not clearly describe a higher risk of complications after pelvic radiation, it is reasonable to assume RC can be more difficult in patients with a history of radiation therapy and that more complications may occur.

Robotic Radical Cystectomy

There is an increasing use of laparoscopic techniques for radical cystectomy, and robotic-assisted radical cystectomy (RARC) now constitutes approximately 13% of all RCs performed in the United States.[161] Specific outcomes and complications of RARC are covered in Chapter 36. It was hoped that RARC would lessen the morbidity and hasten the recovery of RC compared to open techniques. There have been several retrospective and prospective institutional reports on RARC and four randomized controlled trials that have examined the surgical outcomes and complications of RARC in comparison to open RC (ORC).[162–166]

The first trial that randomized patients to ORC or RARC included 41 patients and found that RARC patients had longer operative times, but less blood loss and an earlier time to return of bowel function.[165] There was no difference in LOS between the two groups, but possibly fewer complications after RARC. In a multi-institutional study that randomized 40 patients to ORC and RARC, there were no significant differences in early complications.[166] The RARC group had less blood loss, although there was no difference in transfusion rates. However, RARC patients had slightly faster return of bowel function and fewer patients had a LOS of over 5 days. A recent trial randomized 118 patients to ORC or RARC and observed that RARC patients did not have a lower rate of complications or LOS, but did have less intraoperative blood loss, longer operative times, and greater costs.[163] The last randomized trial included 59 patients who were randomized to ORC, RARC and laparoscopic RC, each performed by a different surgeon.[164] Open RC patients had more low-grade complications at 30 days, but there was no difference in 90-day complication rates. As previously observed, RARC patients had longer operative time, less blood loss, and faster return to solid food; however, LOS was longer and there was no difference in time to flatus.

Taken together, the randomized trials to date generally agree that RARC is associated with less blood loss and longer operative times, but there is no clear advantage in terms of postoperative complications. Some institutional reports suggest RARC may be associated with superior outcomes; however, this may in part be due to patient selection and surgeon experience.[162,167] Although the value of RARC continues to be debated, it is possible that with ongoing experience and refinement of surgical technique, RARC may fulfill the promise of lessening the morbidity of RC.

Conclusions

Despite over half a century of experience with RC, it continues to carry significant postoperative morbidity. The majority of RC patients experience an early postoperative complication, but most complications are minor. There are several methods that can help minimize postoperative complications, including enhanced recovery pathways, restricted fluid protocols, laparoscopic approaches, and referral to high-volume centers. Surgeons who perform RC should be aware of the breadth of postoperative complications that can occur, and be prepared to diagnose and treat complications promptly.

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Chapter 41 Questions

1. A 63-year-old man experiences fevers 12 days after radical cystectomy and is found to have a 4-cm pelvic abscess. A percutaneous drain is placed by interventional radiology under local anesthesia. This is a Clavien-Dindo grade ___ complication.
   a. II
   b. IIIa
   c. IIIb
   d. IV
   e. V

2. All of the following treatments are associated with a faster return of bowel function after radical cystectomy EXCEPT:
   a. Alvimopan
   b. Restricted fluid protocols
   c. Gum chewing
   d. Routine nasogastric decompression
   e. Enhanced recovery protocols

3. A lower rate of surgical site infections has been associated with:
   a. Mechanical bowel preparation
   b. Hair removal
   c. Chlorhexidine-alcohol skin preparation
   d. Intraoperative hypothermia
   e. Fascial closure with interrupted sutures

4. During open radical cystectomy, bleeding is encountered along the right vascular pedicle that you are unable to control. The patient is experiencing major blood loss, hypotension, hypothermia, and coagulopathy despite aggressive resuscitation and transfusion of blood products. The next best step is:
   a. Use a stapler to control the pedicle
   b. Pack the pelvis
   c. Apply topical hemostatic agents
   d. Cell salvage
   e. Hypogastric artery embolization

5. Radical cystectomy is considered a high-risk operation for venous thromboembolism. The recommended prophylaxis for a patient who does not have an unacceptable bleeding risk is:
   a. Early ambulation only
   b. Therapeutic unfractionated heparin
   c. Prophylactic low-molecular-weight heparin AND mechanical prophylaxis
   d. Inferior vena cava filter
   e. Mechanical prophylaxis only

6. Inability to adduct the leg is associated with a(n) ____ nerve injury.
   a. Genitofemoral
   b. Femoral
   c. Obturator
   d. Ilioinguinal
   e. Sciatic

7. Risk factors for postoperative mortality include all of the following EXCEPT:
   a. Older age
   b. Increased patient comorbidity
   c. Low hospital volume
   d. Nutritional deficiency
   e. Neoadjuvant chemotherapy

8. Robotic-assisted laparoscopic radical cystectomy is associated with:
   a. Less intraoperative blood loss
   b. Shorter operative time
   c. More complications
   d. Better outcomes
   e. Lower costs

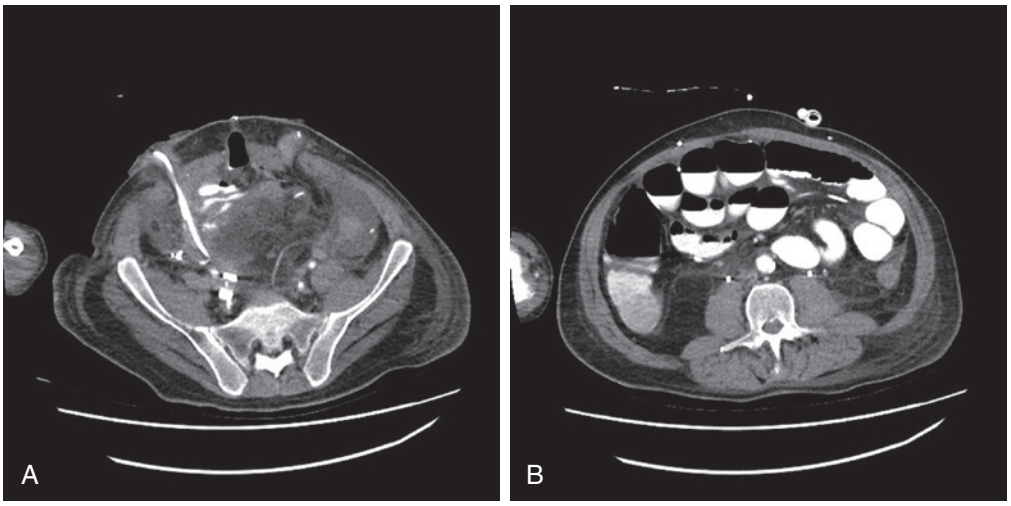
9. A 76-year-old woman presents with left flank pain and fevers 25 days after a radical cystectomy and ileal conduit. CT scan demonstrates left hydroureteronephrosis and a delayed left nephrogram. The next best step is:
   a. Abdominal exploration
   b. Left percutaneous nephrostomy tube
   c. Observation
   d. Placement of a catheter to drain the ileal conduit
   e. Looposcopy and retrograde left ureteral stent

Case Study 1

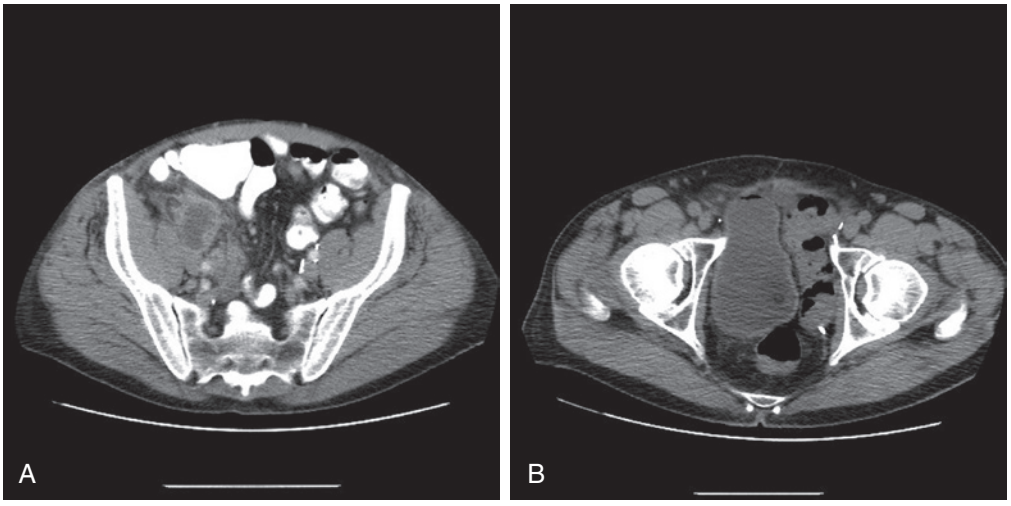
A 56-year-old male with invasive bladder cancer had a radical cystectomy and ileal conduit 5 days previously. His medical history is significant for a prior left proctocolectomy with permenant colostomy, active one pack-per-day smoker, and emphysema. His hospital course was uneventful until postoperative day 5 when he developed nausea and vomiting. He also noted some fluid drainage from his midline incision. On exam, he was distended and there was a large amount of clear fluid draining from the midline incision, but the skin was approximated. CT scan demonstrated fascial dehiscence and a small bowel obstruction with the transition point in a knuckle of bowel above the fascia (Case Fig. 41-1).

1. The next step in the management of this patient is:
   a. Placement of nasogastric tube
   b. Open and pack wound
   c. Exploratory laparotomy
   d. Use of an abdominal binder
   e. Fluid culture

2. Given the association between fascial dehiscence and wound infection, how should the wound be managed following a repeat fascial closure?
   a. Primary closure with subcutaneous drains
   b. Negative pressure dressing
   c. Pack wound and perform regular dressing changes
   d. a or b only
   e. b or c only



Case Figure 41.1



Case Figure 41.2

3. You are performing a radical cystectomy on an elderly obese female with severe COPD whom you suspect is at increased risk for fascial dehiscence. A consideration during primary abdominal closure should include use of:
   a. Multiple interrupted absorbable sutures for fascial closure
   b. External retention sutures
   c. Internal retention sutures
   d. Large fascial bites
   e. Skin stapler

Case Study 2

A 64-year-old male with invasive bladder cancer was treated with neoadjuvant cisplatin-based chemotherapy followed by radical cystectomy, bilateral pelvic lymphadenectomy, and an orthotopic ileal neobladder. His hospital course was uneventful and he was discharged home on postoperative day 6. He returned to the hospital on postoperative day 18 with fevers to 102°F and shaking chills. On exam, his abdomen was soft and he had no costovertebral tenderness. His catheter was difficult to irrigate and did not drain well. Labs were significant for a leukocytosis to 17 and increase in his creatinine from 1.2 (baseline) to 1.7. CT scan demonstrated a distended neobladder and a 4-cm rim-enhancing fluid collection along the right pelvic sidewall (Case Fig. 41-2).

1. Initial choice of antibiotics should include coverage for which of the following organisms?
   a. *Escherichia coli*
   b. *Klebsiella pneumonia*
   c. *Enterococcus*
   d. *Pseudomonas*
   e. All of the above

2. Following prompt administration of intravenous fluids and antibiotics, the next step for managing this patient is:

a. Observation with antibiotics
b. Drainage of pelvic abscess by interventional radiology
c. Exploratory laparotomy with abdominal washout
d. Foley catheter replacement and bladder irrigation
e. b and d only

3. CT cystogram demonstrated a small leak from the afferent limb of the neobladder with reflux into both ureters. The most appropriate management is:
a. Bilateral percutaneous nephrostomy tubes
b. Prolonged indwelling Foley catheter
c. Exploratory laparotomy with repair of leak
d. Conversion to an ileal conduit
e. Intravenous antibiotics

Answers

1. **b**. The complication required intervention without anesthesia (Case Table 41.1).
2. **d**. Routine nasogastric decompression, while broadly used historically, has not been shown to enhance return of bowel function. The remaining choices, while not conclusively proven to causally improve bowel function, have been associated with more rapid recovery of bowel function in comparative studies.
3. **c**. Skin preparation with an alcohol-based preparation solution has been shown to lower wound infection rates. The routine removal of hair is not clearly shown to reduce infection, but if performed should avoid nicks and cuts in the skin, which might promote infection. Hypothermia increases the risk of infection, and neither mechanical bowel preparation nor technique of fascial closure has been associated with infectious risk.
4. **b.** Given the instability of the patient, packing to reduce bleeding is the best choice. A return to the operating room, following stabilization of the patient, might allow more effective control of bleeding if arterial in nature. In general, uncontrolled bleeding from the deep pelvis is a combination of arterial and venous bleeding, and usually embolization or ligation of the hypogastric artery is ineffective.
5. **c.** Cystectomy and urinary diversion would be considered to be high risk according to the American College of Chest Physicians Evidence-Based Clinical Practice Guidelines, 9th edition. As such, prophylaxis should include both prophylactic low-molecular-weight heparin AND mechanical methods.
6. **c.** The obturator nerve, commonly injured during either lymph node dissection or bladder pedicle division, supplies the adductor muscles of the leg. As such, injury results in inability to adduct the leg.
7. **d.** Age, comorbidity, poor nutritional condition, and surgeon/center inexperience are all associated with increased risk of perioperative mortality.
8. **a.** The only proven benefit of robotic-assisted radical cystectomy, as compared to open cystectomy, is a reduction in intraoperative blood loss. Operative time, while surgeon-specific, is generally longer than open. Cost is generally higher as well.

Case Table 41.1 Preoperative Venous Thromboembolism Risk Stratification and Treatment Recommendations for Patients Having Gastrointestinal, Urologic, Vascular, Breast, and Thyroid Procedures

Risk Category	Risk Score[a]	VTE Risk in Absence of Prophylaxis	Recommended Prophylaxis
Very low	0	<0.5%	Early ambulation only
Low	1–2	1.5%	Mechanical prophylaxis, preferably with sequential compression devices
Moderate	3–4	3.0%	■ Pharmacologic[b] OR mechanical prophylaxis, preferably with sequential compression devices OR ■ Mechanical prophylaxis if bleeding risk is high, preferably with sequential compression devices
High	≥5	6.0%	■ Pharmacologic[b] AND mechanical prophylaxis OR ■ Mechanical prophylaxis if bleeding risk is high, preferably with sequential compression devices[c]
High-risk cancer surgery			■ Pharmacologic[b] AND mechanical prophylaxis AND extended duration LMWH post-discharge OR ■ Mechanical prophylaxis if bleeding risk is high, preferably with sequential compression devices[c]

[a]Caprini risk score:
1 point: age 41–60, minor surgery, BMI >25, swollen legs, varicose veins, pregnancy or postpartum (<1 mo), history of unexplained or recurrent spontaneous abortion, oral contraceptives or hormone replacement, sepsis (<1 mo), severe lung disease including pneumonia (<1 mo), abnormal pulmonary function, acute myocardial infarction, congestive heart failure (<1 mo), inflammatory bowel disease, medical patient at bed rest
2 points: age 61–74, arthroscopic surgery, major open surgery (>45 min), laparoscopic surgery (>45 min), malignancy, confined to bed >72 hrs, immobilizing cast (<1 mo), central venous access
3 points: age ≥75, history of VTE, family history of VTE, factor V Leiden, prothrombin 20210A, lupus anticoagulant, anticardiolipin antibodies, elevated serum homocysteine, heparin-induced thrombocytopenia, other congenital or acquired thrombophilia
5 points: stroke (<1 mo), elective arthroplasty, hip, pelvis, or leg fracture (<1 mo), acute spinal cord injury (<1 mo)
[b]LDUH and LMWH both acceptable for pharmacologic prophylaxis
[c]LMWH or LDUH can be added once bleeding risk diminishes
(Adapted from Gould MK, Garcia DA, Wren SM, et al. Prevention of VTE in nonorthopedic surgical patients: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest. 2012;141:e227S-77S.)

9. **b.** Patients with concern for obstructive pyelonephritis require emergent upper tract drainage. This is best accomplished in an antegrade fashion after urinary diversion.

CASE STUDY 1

1. **c.** Fascial dehiscence is a surgical emergency that requires urgent exploration and abdominal closure.

2. **e.** Patients with fascial dehiscence commonly have wound infections in which case primary skin closure should be avoided.
3. **b.** Patients at increased risk of dehiscence can be managed with external retention sutures, which should remain in place for 6 weeks.

CASE STUDY 2

1. **e.** Patients with abdominal infections after cystectomy should be treated with broad-spectrum antibiotics to cover both enteric and urinary pathogens.
2. **e.** Urgent source control is critical for patients with sepsis. In this case, both the abscess and obstructed bladder need to be drained. His bladder is likely obstructed by mucous, thus some gentle irrigation is required to ensure maximal drainage of the neobladder.
3. **b.** A small leak in a neobladder may heal with bladder decompression alone. Aggressive surgery would not yet be indicated in a patient with an active infection and without an attempt at conservative management.

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42 Complications of Radical Retropubic Prostatectomy

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CHAPTER OUTLINE

Preoperative Considerations
Intraoperative Complications
Bleeding
Rectal Injury
Ureteral Injury
Nerve Injury
Early Postoperative Complications
Urinary Leak
Urinary Tract and Wound Infection
Pulmonary Embolus and Deep Vein Thrombosis
Loss of Catheter
Delayed Postoperative Complications
Impotence
Incontinence
Bladder Neck Contracture/Anastomotic Stricture
Minor Complications
Salvage Prostatectomy
Chapter 42 Questions and Answers

KEY POINTS

1. When performing open radical prostatectomy, the rate of bleeding varies with operator experience and technique. The use of preoperative erythropoietin or autologous blood donation can lower the likelihood of allogeneic transfusion greatly.
2. Control of the dorsal venous complex prior to division can greatly reduce blood loss during radical prostatectomy. Accurate and complete bunching of the dorsal vein hood over the base of the prostate is helped by wide incision of the endopelvic fascia back to the bladder neck.
3. Early release of the lateral prostatic fascia on the anterolateral surface of the gland facilitates release of the neurovascular bundles prior to urethral division, thereby reducing traction on the neurovascular structures.
4. In performing the urethral anastomosis, tension-free mucosal apposition is essential in avoiding bladder neck contracture.
5. Pelvic hematoma due to postoperative bleeding causes distraction of the urethral anastomosis, potentially causing urinary extravasation and eventual bladder neck contracture. In such cases prolonged catheterization is warranted.
6. Rectal injury at the time of radical prostatectomy does not require diverting colostomy in the majority of cases. Bowel preparation, antibiotics, methodical closure of the rectum, and interposition of either omental or peritoneal closure of the rectum, and interposition of either omental or peritoneal flap can all help in avoiding the need for colostomy.
7. Long-term satisfaction with postoperative urinary and sexual function outcomes relies upon careful discussion with patients to assess risk factors and set expectations.
8. Bleeding complications strongly influence urinary function outcomes, and thus every effort should be made to minimize rates of these complications.

The description of the anatomic nerve-sparing radical retropubic prostatectomy (RRP) by Walsh[2] in 1983 revolutionized the technique. Consequently, the comfort level of urologists performing the procedure has risen to meet the increased need for radical prostatectomy in the current era of prostate-specific antigen testing. Despite numerous options for treatment of localized disease, radical prostatectomy remains the urologic gold standard of treatment.

The complication rate for radical prostatectomy appears to have declined with technical modifications to the operation and increasing experience of urologic surgeons.[3,4] Surgical morbidity following radical prostatectomy is influenced by many factors including the experience of the surgeon, the age and medical comorbidities of the patient, the size of the prostate, the anatomy of the pelvis, the volume of prostate cancer, and the use of preoperative hormonal ablation

or radiation. Intraoperative complications include bleeding, rectal injury, nerve injury, and, in rare circumstances, ureteral injury. Early postoperative complications include urinary leak, infection, deep vein thrombosis or pulmonary embolus, and loss of the urethral catheter. Delayed postoperative complications generally present the greatest problem to the patient. These include incontinence, impotence, voiding dysfunction, and bladder neck contracture.

Preoperative Considerations

Men presenting with prostate cancer range in age, disease aggressiveness, and goals of treatment. Today, the treatment options for localized disease include active surveillance, radical prostatectomy, radiation therapy, and focal or whole gland ablation. Selection of a treatment modality for localized prostate cancer is multifactorial and requires extensive counseling. Realistic preoperative expectations on the part of the patient are a critical determinant of postoperative satisfaction.[5] The process of preoperative education mandates a comprehensive review of all reasonable therapeutic options and their potential complications and relative outcomes.

In general, candidates for radical prostatectomy should be in good health. In contemporary prostatectomy series, the risk of myocardial infarction, pneumonia, cerebrovascular accident, and death from these causes is exceedingly low,[4,6–9] likely because of proper patient selection, surgeon experience, and improved anesthesia techniques.[7–9] Selection of healthy surgical candidates is important not only from the standpoint of avoiding anesthesia-related morbidity but also because the relative advantage of surgical resection over radiation-based therapies lies in the duration of therapeutic response.[10]

The preoperative assessment varies according to comorbidities. Men with significant hypertension, coronary artery disease, and diabetes should undergo medical clearance to ensure these disease states are optimally managed. If there is an individual or significant family history for deep venous thrombosis or pulmonary embolus hematologic consultation is recommended in order to identify genetic predispositions to these untoward events. A plan for preoperative and postoperative anticoagulation management should be defined in consultation with the cardiologist or neurologist for men with coronary stents, valvular replacement, atrial fibrillation, or prior cerebral vascular accidents.

A cardiology consultation may be advisable for men with no history of significant atherosclerotic cardiovascular disease and preoperative erectile dysfunction or significant family history of atherosclerotic cardiovascular disease in order to identify occult disease. Erectile dysfunction may represent the first sign of significant atherosclerotic cardiovascular disease.[11]

Sleep apnea is a condition that is often undiagnosed and associated with obesity. The presence of sleep apnea may influence decisions regarding postoperative pain management. Therefore men with obesity should be queried about symptoms suggestive of sleep apnea.

Individuals with expected longevity >15 years are ideal for the procedure since they are likely to achieve the benefits of both survival and prevention of metastasis even if they present with lower risk disease. In assessing a patient's longevity, the urologist must carefully weigh the aggressiveness of the disease against the patient's health. Higher-grade cancers, which are more likely to result in disease-related morbidity in the short term, may require aggressive therapy in patients with relatively short longevity, whereas radiation-based therapies or watchful waiting may be more important in individuals with moderately differentiated disease and relatively poor health.

In this regard, Albertsen and colleagues[12] described the risk of cancer-related death in 15 years of diagnosis for individuals with various grades of prostate cancer. The estimated risk of death in men managed without curative intervention was 4–7% in patients with Gleason score 2 to 4, 6–11% in patients with Gleason score 5, 18–30% in patients with Gleason score 6, 42–70% in patients with Gleason score 7, and 60–87% in patients with Gleason score 8 to 10. Clearly, individuals with higher-grade disease have worse outcomes with radical prostatectomy than do patients with low-grade disease, but prediction of outcome must be balanced against disease-related risk of death.

In selecting candidates for radical prostatectomy, the presence of voiding dysfunction and prostate size should be carefully elucidated. Individuals with significant preoperative obstructive voiding symptoms may actually experience relief of such symptoms following radical prostatectomy and a reduced risk of subsequent acute urinary retention.[13,14] Preoperative prostate volume was inversely related to positive surgical margins and directly related to blood loss and transfusion rates.[15] Conversely, such individuals, particularly those with large prostates, may experience a worsening of voiding symptoms or progression to urinary retention following radiation-based treatments. The improvement in quality of life resulting from the relief in voiding symptoms following radical prostatectomy may actually outweigh the detriment caused by mild degrees of stress incontinence in the view of the patient[5,16,17] Lepor et al. ascertained the long-term impact of radical prostatectomy on lower urinary tract symptoms.[5,17] At 10 years following surgery, the overwhelming majority of men with preoperative moderate/severe lower urinary tract symptoms (LUTS) experience durable resolution of their symptoms whereas those with mild preoperative LUTS do not develop worsened LUTS.

Radical prostatectomy is the only treatment that has been compared to watchful waiting. The Scandinavian Prostate Cancer Group Study Number 4 demonstrated an absolute risk reduction of approximately 6% for dying of prostate cancer for men undergoing radical prostatectomy versus watchful waiting at 12–15 years of follow-up. Radical prostatectomy conferred a similar risk reduction of developing distant metastases at 12 years as well. This reduction was greatest for men who were less than 65 years of age at the time of diagnosis.[18]

A careful assessment of the patient's daily activities and profession may aid in determining the potential impact of stress urinary incontinence on the individual surgical candidate. Although rates of significant incontinence have drastically improved, the patient should be made well aware of the nature and potential impact of stress urinary incontinence. Similarly, the risk of impotence despite nerve-sparing procedures should be carefully delineated. The preoperative factors influencing preservation of potency include age,

baseline sexual function, history of diabetes, preoperative use of phosphodiesterase inhibitors and the extent of nerve sparing.[19] Although pharmacologic advancements in the field of erectile dysfunction have lessened the impact of postoperative impotence following radical prostatectomy, the presence of a regular sexual partner, the stability of current relationships, and cultural attitudes regarding erectile dysfunction should be carefully evaluated before the surgical procedure.

The overall impact of complications of radical prostatectomy on quality of life is a topic of intense study in many centers. Future focus will lie in preoperative identification of poor candidates for surgery on the basis of potential impact of surgical complications on quality of life.

Intraoperative Complications

BLEEDING

Bleeding during RRP is most commonly encountered during division of the dorsal venous complex of the penis. Before the description of the anatomic approach to radical prostatectomy by Walsh, severe hemorrhage was often encountered during uncontrolled division of the venous complex. On occasion, such bleeding was severe enough to require cutdown onto the prepubic penile shaft and identification of the retracted, uncontrolled venous complex beneath Buck's fascia for ligation.

Despite the advances in surgical technique, the potential for significant bleeding during division of the dorsal venous complex and the remainder of the procedure still exists. The mean intraoperative blood loss reported in large series of radical prostatectomy has varied tremendously and ranges from 579 mL to >2 L and is likely influenced by operative technique, the presence or absence of nerve sparing, time, and the experience of the surgeon.[7,20,21] Several surgeons have suggested various means of perioperative blood management to minimize the need for transfusion. Rates of allogeneic transfusion in contemporary series have varied from 2.4% to 21% independent of autologous blood donation.[21–26] Reoperation for bleeding is extremely rare, with a reported incidence as low as 0.3%[26] and 0.6%[9] in two large series.

The use of autologous blood donation was previously shown to reduce the risk for allogeneic transfusion. Several investigators challenged the need for blood donation.[24,27,28] Koch and Smith[24] reported an overall transfusion rate resulting from intraoperative bleeding of 2.4% in 124 patients undergoing radical prostatectomy without preoperative autologous blood donation. Because it is unlikely that most surgeons will be fortunate enough to experience such a minimal likelihood of intraoperative and postoperative bleeding, it is advisable that some form of preventive management be instituted in patients undergoing radical prostatectomy.

One of the limitations of autologous blood donation is all men are destined to have significant preoperative and postoperative anemia. It has been estimated that the endogenous response to autologous donation produces about one unit of red blood cells.[29] Because of potential risks associated with transfusing autologous blood, the indications for transfusing autologous and allogeneic blood are similar. Therefore the only men who benefit from autologous blood are those who have significant bleeding and require replacement of all three stored units. Therefore the impact of autologous blood donation is a modest reduction in allogeneic blood transfusion at the expense of significant postoperative anemia.

Sultan et al. have reported that return to work and physical activities are dependent on discharge hemoglobin and timing for removal of the urinary catheter.[30] Therefore a blood management strategy should consider both the potential advantages of decreasing allogeneic transfusion rates and minimizing postoperative anemia.

Chun and associates proposed the use of preoperative erythropoietin injections instead of autologous donation.[29] Patients were given one to two injections of erythropoietin, provided their preoperative hematocrit was <48%.[29] On average, an increase in the hematocrit of 3% was noted when 600 U/kg was administered 7–14 days preoperatively. Using this method, the investigators demonstrated an identical risk of allogeneic transfusion in individuals donating autologous blood. Based on safety, efficacy, and dose ranging studies, we currently recommend administering epoetin alfa 300 IU/kg 7 and 14 days preoperatively in men with a baseline hematocrit <48%.[31,32] The postoperative hemoglobin of the group receiving erythrocyte-stimulating proteins was significantly greater than in the autologous blood donation group. The short- and long-term cardiovascular and oncologic safety of erythrocyte-stimulating proteins has been demonstrated.[33,34]

Although dorsal venous complex bleeding can occur regardless of the chosen technique of control, several anatomic points can be helpful for avoiding profuse hemorrhage. The dorsal venous complex courses beneath the pubis symphysis as a bundle of veins over the membranous urethra before it fans over the anterior surface of the prostate and bladder neck. On uncontrolled division, variable amounts of bleeding can occur. Initial descriptions of the anatomic retropubic prostatectomy included isolation of the dorsal venous complex with passage of a right-angle clamp between the membranous urethra and the complex, followed by sharp division with a knife blade. We have, in recent years, chosen to ligate the complex proximally and distally before division.

The dorsal venous complex is covered by an overlying reflection of the endopelvic fascia. To control all the veins fanning over the prostate within the complex effectively, the endopelvic fascia must be fully incised along the lateral sulcus of the anterior prostate. Removing the periprostatic adipose tissue overlying the anterior surface of the prostate allows visualization of the structures required to control the dorsal venous complex. This incision is made in the groove between the prostate and levator musculature during gentle retraction of the prostate contralaterally (Fig. 42.1A). The incision must be carried to the apex of the prostate and bladder neck to allow effective mobility of the proximally located veins. Small perforating vessels may be controlled with surgical clips.

A decussation of the endopelvic fascia, termed the *puboprostatic ligament,* lies at either lateral edge of the venous complex fusing its anterior surface to the posterior surface of the pubic bone. We do not routinely divide the puboprostatic ligaments unless they fan laterally and limit placement of the distal suture ligature controlling the dorsal venous

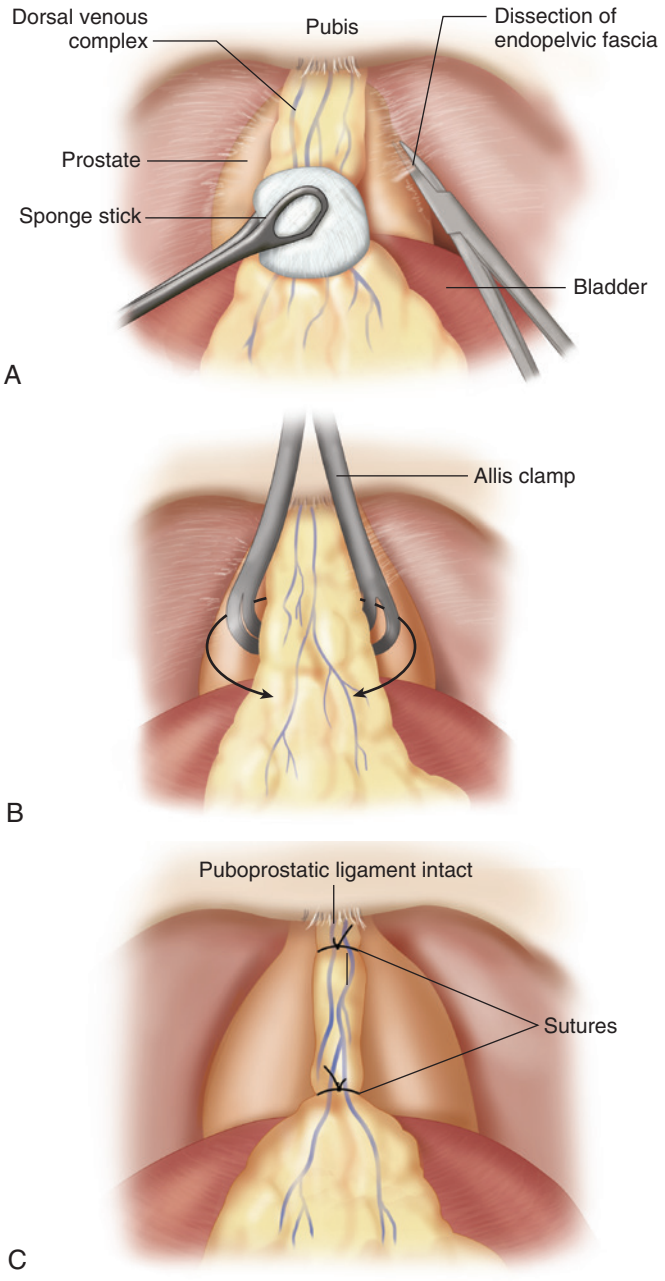


Figure 42.1 The technique of dorsal venous complex control. A, The endopelvic fascia is sharply incised on either side of the prostate. The incision extends from the base of the prostate to the puboprostatic ligament. B, An Allis clamp is used to bunch the dorsal venous complex centrally. The initial bunching is done over the midprostate, proximal to the prostatic apex. Bunching is performed by inserting the jaw of the clamp into the endopelvic fascial incision on each side and thereby incorporating all veins as they fan over the prostate. C, Proximal and distal bunching sutures are in place in the dorsal venous complex. The surface of the anterior prostate reveals no excluded veins coursing over the gland. The first suture is placed proximally at the level of the bunching clamp. A second suture is then placed distal to the puboprostatic ligaments, around the dorsal venous complex, as far caudad as possible without division of the puboprostatic sutures. (From Tareen B, Godoy G, Taneja SS, Complications of Radical Retropubic Prostatectomy, in Complications of Urologic Surgery: Prevention and Management, 4th Edition, Taneja SS (ed), Saunders Elsevier, Philadephia, PA, 2010.)

complex. Incising the puboprostatic ligament may facilitate dropping the venous complex away from the pubis. This is particularly useful when operating on large glands that compress the dorsal venous complex or glands with a large anterior or retropubic component and when the puboprostatic ligaments extend onto the anterior surface of the prostate gland. In these situations, we divide only that portion of the puboprostatic ligament needed for exposure. Preservation of the puboprostatic ligament will hold the vein stump fixed, to some extent, and prevents retraction and uncontrolled bleeding.

Once the endopelvic fascia has been incised on either side of the gland and the superficial dorsal vein has been defined and fulgurated, the deep venous complex is bunched centrally for control (see Fig. 42.1B). One approach is to use an angled or straight long Allis clamp inserted with one jaw in each facial incision. The venous complex is then bunched centrally at the level of the midprostate, with care taken to include all veins but avoiding prostatic capsular injury. Difficulty with bunching may be corrected with further proximal incision of the endopelvic fascia. Once the clamp is in place, the venous complex is controlled with a suture ligature of 2-0 polyglactin 910 (Vicryl) on a wide curved needle, at the level of the clamp placement. The clamp is removed during ligation of the proximal vein. Next, a suture ligature is placed around the distal venous complex as far caudal as possible (see Fig. 42.1C). This is achieved by placing the Allis clamp more apically and gently depressing the visible prostatic apex, thus exposing the distal vein as it courses over the membranous urethra. Double passage of each suture ligature will fix it in place and prevent it from slipping off on division of the vein. Alternatively, securing the proximal suture ligature at the midgland can serve the same function as the Alis clamp.

Sharp incision of the dorsal venous complex is then initiated between the proximal and distal sutures (Fig. 42.2). A plane of dissection is developed sharply within the dorsal complex, with great care taken not to injure the anterior prostatic capsule. A sponge stick is used by the assistant to retract the prostate cranially and gently roll it away from the pubis as the venous tissue is divided. The surgeon should always err on the side of cutting out the distal suture rather than injuring the anterior prostate. If the distal suture is cut out, complete division of the dorsal venous complex should be completed, and then the dorsal venous complex stump can be directly suture ligated. Incision of the dorsal venous complex is sequentially carried out until the anterior urethra is exposed. An effort should be made to preserve the anterior thickness of the urethra maximally.

An alternative approach and advantage of the open approach is the ability to palpate the prostatourethral junction between the thumb and forefinger. A McDougal clamp is then passed at this precise location in order to guide division of the dorsal venous complex so that the entire complex is divided while maximally preserving the rhabdosphincter.

Bleeding can occur throughout the procedure. This bleeding often originates from the bed of the neurovascular bundle if nerve sparing is performed, from the seminal vesicular arteries, or from the bladder neck. The surgeon must balance securing hemostasis while minimizing trauma to the neurovascular bundles. Using a lap pad to pack the pelvis is an effective technique to minimize pelvic bleeding during the

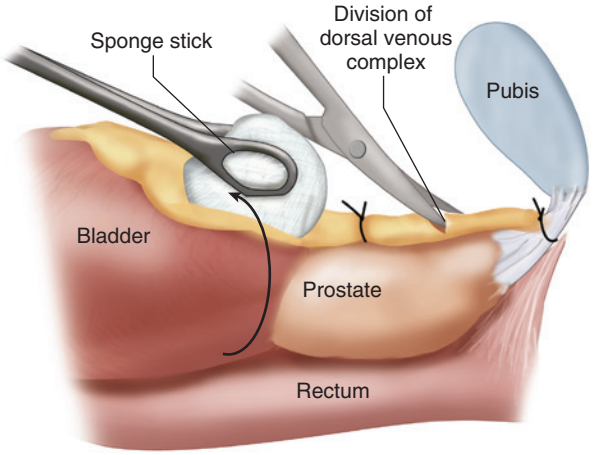


Figure 42.2 Division of the dorsal venous complex begins by incising the centrally bunched tissue between the proximally and distally placed sutures. A sponge stick is used to rotate the gland dorsally and cranially away from the pubic symphysis as the dorsal complex is divided. In doing so the dorsal complex is rotated into the field as it is sequentially divided. Antegrade dissection is carried out within the dorsal venous complex until the membranous urethra is rotated into the field of view. Caution must be exerted to avoid anterior prostate injury. (From Tareen B, Godoy G, Taneja SS, Complications of Radical Retropubic Prostatectomy, in Complications of Urologic Surgery: Prevention and Management, 4th Edition, Taneja SS (ed), Saunders Elsevier, Philadephia, PA, 2010.)

dissection and minimizes blood loss through venous compression. The prostatic pedicles are usually directly ligated before division and for this reason should not be a major source of bleeding. Bleeding from the neurovascular bundles can occasionally be controlled by clipping prostate perforating branches before division, but this is often a fruitless endeavor. In a nonnerve-sparing procedure, early ligation of the neurovascular bundle can save a great deal of trouble when one tries to suture ligate the stump once it is retracted. When steady bleeding is encountered, it is usually best to move ahead with the procedure because operative time likely predicts the cumulative blood loss. Fulguration or clipping of the neurovascular bundles may inadvertently injure the nerve and therefore should be avoided.

Some investigators have advocated an antegrade approach to radical prostatectomy to avoid early bleeding, but in general, if the procedure is to be performed in a timely fashion with early control of the dorsal venous complex, this should not be necessary.[35]

In a personal experience of almost 5000 cases, intraoperative control of bleeding was not achievable in a single case and the patient was closed after tightly packing the pelvis with multiple lap pads. The lap pads were removed the following day with preservation of anastomotic integrity.

Significant and life-threatening hemorrhage typically occurs within a few hours after completion of the case. The surgeon is confronted with the decision to return immediately to the operating room or attempt conservative management with the hope bleeding will spontaneously subside. Significant blood in the pelvis is associated with prolonged hospitalization and catheter drainage with increased likelihood of strictures. In cases with significant hemodynamic instability due to bleeding, we recommend immediate return to the operating room to control bleeding, evacuate the pelvic hematoma, and re-do the anastomosis if necessary.[36] This approach results in an expedited recovery and limits postoperative strictures and incontinence.

RECTAL INJURY

Injury of the rectum occurs in <1–3.6% of patients undergoing radical prostatectomy.[4,6,9,37,38] Risk factors for rectal injury include small prostates, previous radiation, and periprostatic inflammation resulting from previous transurethral resection or excessive bleeding at the time of biopsy. Salvage prostatectomy carries the highest rates of intraoperative rectal injury, with reports ranging from 6% to 15%.[39,40] Immediate repair of the injury results in excellent outcome without long-term sequelae in the majority of patients.

Following division of the posterior urethra, the surgeon encounters the rectourethralis muscle along with underlying Denonvilliers' fascia. It is desirable to divide this layer in a single incision and thus enter the pararectal space and allow an adequate posterior margin of resection. If the surgeon is too timid in division, aggressive retraction of the prostatic apex can result in shearing of Denonvilliers' fascia from the posterior apex and splitting of the gland. If the surgeon is too aggressive in achieving this plane, sharp injury of the rectum can occur. In general, rectal injury results from an overzealous attempt to develop the posterior plane bluntly with the tip of the finger. If the rectourethralis is not completely divided, or if the plane does not develop easily with blunt dissection, the attached rectal wall can be torn. Sharp dissection is preferable if the apex of the gland does not lift away from the rectum easily. It is also advisable to first incise the visceral layer of the endopelvic fascia and develop the plane between the prostate and rectum beginning laterally. An obscured operative field from excessive bleeding hinders the ability to see the tissue planes clearly. Therefore adequate hemostasis is preferable at the time of the apical dissection.

When rectal injury does occur, it is generally acceptable to repair the defect primarily in the absence of gross fecal soiling.[37,41,42] Patients should have been given a preoperative enema specifically for this reason. Débridement of devitalized tissue at the site of laceration should be followed by a two-layer closure of mucosal and muscular layers of the rectal wall. A small opening can be made in the peritoneum to pull down and interpose an omental flap between the rectal repair and the vesicourethral anastomosis. Although this maneuver is not routinely necessary, it can provide an extra safety measure if the surgeon is concerned about the viability of the rectal closure. A pedicalized flap of peritoneum or pararectal fat can serve a similar purpose. In the event of a large injury, a significantly devitalized or devascularized rectal wall, or the presence of gross soiling, serious consideration should be given to a temporary diverting colostomy along with simultaneous rectal wall repair. This procedure is certainly advisable in the setting of a previously irradiated pelvis.

The risk of rectourethral fistula following repair of rectal injury is lowered.[42] Use of prolonged bowel rest, anal dilation at the time of the surgical procedure, and the administration of broad-spectrum antibiotics have all been suggested as potential aids in lowering fistula rates.

Perhaps the greatest risk of fistula formation and risk of morbidity stem from unrecognized rectal injury.[37] If a rectourinary fistula does develop and the patient is otherwise well, an initial attempt at conservative management can be attempted using bladder drainage and a low-residue diet. Complicated cases or patients with a history of radiation will likely require use of a temporary diverting colostomy.[43]

URETERAL INJURY

Ureteral injury during radical prostatectomy is rare, occurring in 0.05–1.6% of cases.[6,9,44,45] When it does occur, it is usually during the bladder neck division, although with many surgeons advocating extended lymphadenectomy, the ureter may be injured above the iliac bifurcation during node dissection. In the setting of a large median lobe, care must be exercised to avoid the ureteral orifices by directly visualizing them. We prefer to use a partial bladder neck–sparing approach, and when doing so, caution must be exerted to avoid straying into the trigonal musculature.

The administration of intravenous indigo carmine on division of the bladder neck should be routinely performed to visualize ureteral efflux on both sides. This is particularly true for the surgeon inexperienced in prostatectomy, but is a good general habit for all surgeons. Occasionally, in a patient who has undergone aggressive transurethral resection of the prostate, the ureteral orifices can be cut during division of the bladder neck. Our simple solution is to perform a ureterotomy for a length of approximately 1 cm, insert an indwelling stent, and then taper the bladder neck posteriorly to relocate the orifices proximally.

On rare occasions, injury to the ureter can occur during posterior dissection of the seminal vesicles. The ureters generally enter the posterior bladder wall anterolateral to the tips of the seminal vesicles and cross toward the midline above the trigone. For this reason, blind placement of sutures should be avoided in the seminal vesical bed. If one suspects an injury, passage of a 3Fr feeding tube can allay concerns. In rare circumstances, an on-table retrograde pyelogram can be helpful.

If ureteral injury is identified, immediate ureteroneocystostomy is indicated. The cut end of the ureter is pulled into the bladder lumen at a convenient site, spatulated, and sutured to the bladder mucosa. A long submucosal tunnel is not necessary. The vesicourethral anastomosis should be completed first to avoid tension on the ureteral anastomosis. Similarly, if tension is encountered, a Boari flap is preferable to a psoas hitch to avoid undue tension on the vesicourethral anastomosis. Ultimately, this injury remains very rare for experienced surgeons. Heightened operative vigilance is needed when normal anatomic boundaries and tissues have been altered by severe inflammation and fibrosis. For example, in a series of 1500 consecutive open radical prostatectomies, the only case of a ureteral injury occurred in a patient with unrecognized schistosomiasis who had extensive pelvic fibrosis.[9,32]

NERVE INJURY

Injury to the obturator nerve and femoral nerve can occur during pelvic mobilization, and these injuries are discussed in detail in Chapter 40.

Early Postoperative Complications

URINARY LEAK

At our institution, men undergo a cystogram prior to removal of the urinary catheter. The incidence of significant urinary extravasation on postoperative days 3 to 4 versus day 7 is 9.9% and 13.3%, respectively.[46,47] The observation that the overwhelming majority of anastomoses are essentially water tight by postoperative day 3 suggests that a fibrin plug and not collagen deposition allows for early anastomotic integrity. The urinary catheter can be safely removed in cases with slight extravasation on cystogram.[48] While an intraoperative evaluation of the anastomotic integrity may serve to allay surgeon concerns, early anastomotic integrity has been shown to be independent on the degree of intraoperative urinary extravasation noted.[47] Therefore a watertight anastomosis does not facilitate healing of the anastomosis and early removal of the urinary catheter. Fenig and colleagues observed that postoperative blood loss was associated with the degree of extravasation on postoperative cystogram.[49] This same relationship was not true of intraoperative blood loss, a finding that left the investigators to conclude that postoperative blood loss resulted in a hematoma that may cause distraction of the vesicourethral anastomosis. A subsequent study quantifying the volume of the perianastomotic hematoma indicated that all anastomoses are watertight by postoperative day 7 if the volume of the perianastomotic hematoma is less than 37 milliliters.[50] Therefore achieving hemostasis is the primary, if not the only, factor influencing the integrity of the anastomosis.

Men with significant pelvic hematoma typically develop significant bleeding around the urinary catheter between postoperative day 3 to 5 after straining to have a bowel movement. The cessation of bleeding around the catheter is an indication the hematoma has resolved. In most cases of significant postoperative bleeding, the output from the pelvic drains is minimal unless there is significant dehiscence of the anastomosis.

When there is persistent drainage from the pelvic drains it is imperative to determine if the fluid is urine or lymphatic fluid by measuring urine creatinine and glucose. If the pelvic drains or a cystogram demonstrates significant urinary leak, a combination of continued catheter drainage with retropubic drainage should allow closure of the leak in a short time. Pelvic suction drains can be used following radical prostatectomy, but if a leak does occur, consideration should be given to converting to gravity drainage by removing the suction bulb. Additionally, if a leak persists, gradual withdrawal of the drain can ensure that the drain tip has not migrated into the anastomosis. If the patient has significant hematuria, periodic gentle irrigation of the catheter is wise to maintain drainage. Clot retention, or catheter plugging resulting from clot, can cause leakage in the early postoperative period. Leaks persisting for greater than 7 to 10 days are concerning to the surgeon, but a steadfast approach of maximal drainage should be maintained. Repeat exploration is hardly ever necessary.

Complete disruption of the anastomosis resulting from pelvic hematoma or seroma is a rare occurrence. Even in this setting, if the anastomosis is stented with a catheter, healing should occur. Obviously, the likelihood of bladder neck contracture is high with significant disruption of the anastomosis, and if it is relatively early in the postoperative period, consideration should be given to surgical revision of the anastomosis along with drainage of the hematoma or seroma. If significant time has elapsed since the surgical procedure, the surgeon may encounter technical difficulty with the anastomosis because of tissue friability and distortion.

In the setting of fever or pelvic pain accompanying a leak, consideration should be given to the possibility of an undrained pelvic fluid collection. Cross-sectional imaging along with percutaneous drainage can relieve the problem if it is identified.

URINARY TRACT AND WOUND INFECTION

Infectious complications following radical prostatectomy are relatively unusual. The incidence in contemporary series ranges from 0% to 3%, generally consisting of wound infection.[4,9,38,51,52] Early recognition of wound infection is essential to minimize the need for aggressive therapy. Patients generally at risk include those with excessive abdominal pannus and those with large amounts of urinary extravasation.

The use of prophylactic antibiotics in radical prostatectomy is essentially the same as in individuals undergoing other forms of abdominal surgery. Antibiotic coverage should be broad spectrum and directed toward skin flora. We routinely use a first-generation cephalosporin administered at the time of anesthetic induction and maintained for a period of 24 hours after the procedure. Because patients have an indwelling catheter for 1 week postoperatively, the use of urinary tract prophylaxis is advocated by some surgeons following surgery. The use of antibiotics for a prolonged period postoperatively is controversial, and the benefit is not clearly demonstrated. Nonetheless, in view of the fresh incision, the risk of small amounts of urinary extravasation, and the risk of catheter-related secondary infections, we generally administer a fluoroquinolone until 2 days following catheter removal.

Before the surgical procedure, a urine culture is advisable. Individuals with known infection should obviously be fully treated before the operation. These individuals should then have prophylactic antibiotics directed toward the offending organism.

Wound infection can result in any patient, but in general patients with significant urinary extravasation, bleeding, or excessive subcutaneous fat may be at the greatest risk. In individuals believed to be at risk because of obesity, the use of a suprafascial subcutaneous suction drain can prevent seroma formation and limit the risk of infection. Additionally, relatively loose approximation of the skin allows drainage of serous and serosanguinous fluid and thereby limits the risk of fluid collection. Subcutaneous sutures to close the "dead space" should be avoided in this situation.

When infection does occur, it is best treated by opening the incision and allowing healing by second intention. On rare occasions, periodic débridement may be required to remove devitalized tissue. The fascia underlying the infection should be carefully inspected for dehiscence, which is rare with an extraperitoneal lower midline incision. If persistent wound drainage is noted, consideration should be given to the possibility of a urine leak or a pelvic abscess.

PULMONARY EMBOLUS AND DEEP VEIN THROMBOSIS

Thromboembolic complications continue to be a major complication of pelvic cancer surgery. Although the diagnosis and management of deep vein thrombosis and pulmonary embolus are discussed in Chapters 2 and 4, routine preventive measures are an important part of radical prostatectomy. The incidence of deep vein thrombosis or pulmonary embolus in contemporary radical prostatectomy series has varied from 0.4% to 3.1%.[4,6,9,38,51,52] This rate is consistent with the 1–5% reported rate of patients undergoing surgical treatment of cancer of the abdomen and pelvis.[53] Much discussion has centered on the routine use of heparinoid prophylaxis for procedures that place the patient at high risk for venous thromboembolism. In a review of 1373 RRPs, Koya and Soloway and their associates [54] found only three instances of deep vein thrombosis with no clinical pulmonary embolus when they used only sequential compression devices and no heparinoid prophylaxis. Lepor and colleagues[26] found similarly low rates in their series of 1000 cases, and as such the use of prophylaxis remains controversial.

LOSS OF CATHETER

Occasionally, as a result of catheter malfunction or injury, the Foley catheter can fall out following radical prostatectomy. This complication is obviously of more concern 7 hours postoperatively than 7 days afterward. In the very early postoperative period (<48 hours), it is unwise to attempt blind passage of a catheter. The use of a flexible cystoscope with passage of a floppy guidewire and then a Councill-tip catheter is the safest course of action. Although it is not absolutely necessary to perform this procedure while the patient is under anesthesia, it is probably most comfortable for the patient in this early postoperative period.

If one is unable to penetrate the anastomosis, or if the anastomosis is disrupted, then placement of a suprapubic cystostomy under ultrasound guidance can temporize the situation. If no urethral catheter is placed, the patient will be at high risk of bladder neck stricture with a suprapubic tube in place. On rare occasions, if nothing can be passed through the anastomosis, reoperation with replacement of the catheter and revision of the anastomosis are indicated. Although reoperation is hardly ever necessary, when it is indicated and there is at least partial integrity of the anastomosis, an attempt should first be made to pass a catheter transurethrally and manually guide it into the bladder. If this is not feasible, it is best simply to perform a cystostomy and attempt antegrade passage of a catheter to establish the lumen. A wire can then be passed through the catheter for eventual retrograde catheter passage. This technique is preferable to disruption and reconstruction of the vesicourethral anastomosis.

Similarly, in the presence of unusually severe hematuria or clot retention, the surgeon should consider placement of an open or closed suprapubic cystostomy rather than catheter change. Urinary drainage can be maintained with the cystostomy while the nonfunctional urethral catheter continues to stent the vesicourethral anastomosis.

In the later postoperative period (>2–5 days), consideration should be given to leaving the catheter out as long as the patient is not in urinary retention. A retrograde urethrogram can confirm closure of the urethra. Alternatively, at this later stage, gentle passage of a catheter is usually possible at the bedside. For those patients falling in between (1–2 days), an attempt at bedside flexible cystoscopy with passage of a wire is usually acceptable, but blind passage of a catheter should be avoided. An unsuccessful attempt can be followed by one while the patient is under anesthesia.

For a discussion of risk factors and management options regarding lymphoceles following pelvic lymph node dissection, please refer Chapter 40.

Delayed Postoperative Complications

IMPOTENCE

Erectile dysfunction following radical prostatectomy was the primary impetus for the development of the modified anatomic approach to RRP described by Walsh. Before the anatomic description of the neurovascular bundles containing the cavernosal nerves, erectile function after radical prostatectomy was rare. Now, with the application of nerve-sparing techniques, investigators report potency in 63% to 68% of men undergoing bilateral nerve-sparing procedures and in 41% to 50% of those undergoing unilateral nerve-sparing operations.[2,4,6] A more rigorous and reliable assessment of erectile function was reported by Marien et al.[55] All men signed informed consent to participate in a longitudinal prospective outcomes study where sexual function was captured at baseline and predefined time points during follow-up using validated self-administered questionnaires and the operating surgeon was not involved in data acquisition, entry, or retrieval. This study reported potency rates of 61% and 47%, respectively, in men undergoing bilateral versus unilateral nerve sparing procedures. Most reported series are from centers of excellence, and the reported rates of potency from community-based series are often lower, ranging from 11% to 30%.[1,56,57]

The assessment of postoperative potency is a critical factor in determining outcomes in prostate cancer surgery. Use of a validated instrument for the measurement of sexual function is critical.[58] Potency is clearly not a binary variable, and it should be treated as a graded phenomenon. Decreased preoperative erectile function is an important determinant of the likelihood of postoperative erections after nerve-sparing surgery.

Several factors influence the likelihood of retaining erectile function postoperatively. Age is a primary determinant of the success of bilateral nerve-sparing prostatectomy in preserving potency adequate for sexual intercourse. The potency rate following bilateral nerve-sparing radical prostatectomy for men <50 years old has varied from 86% to 91% compared with 75% to 80% in men in their 50s, 58% to 60% in men in their 60s, and 25% to 42% in men >70 years old.[2,4,6,59] Although it is difficult to quantitate, preoperative erectile function may be the greatest predictor of age-related return of potency. Historically, preservation of potency was reported at 18 months. Lepor and associates observed that 19.8% of men will experience marked to moderate improvement in erectile function between 2 and 4 years.[60] Longer-term studies have shown further improvement in potency in a small cohort of men up to 7 years.[61] Those men who exhibit long-term improvement in erectile function are those whose erection has shown signs of return. Men with no erectile function at 2 years are unlikely to achieve any functional return of erection.

In addition to patient characteristics contributing to postoperative erectile dysfunction, certain technical factors aside from cavernosal nerve preservation may contribute to this outcome as well. We believe that excessive traction, manipulation, or local cauterization of the neurovascular bundles can greatly influence the likelihood of return of function. Recognition of the nerve bundle and careful preservation of its surrounding tissues are exceedingly important in avoiding nerve injury. Neurapraxia caused by traction or thermal injury may reverse, but the increasing suggestion is that prolonged periods of postoperative erectile dysfunction may increase the likelihood of permanent impotence.

On occasion, when dividing the dorsal venous complex and or lateral periurethral tissues, the surgeon encounters bleeding in the space lateral to the urethra. This complication is most often the result of a lacerated venous branch that is partially retracted beneath the levator musculature. Care should be exercised to avoid electrocautery and or placement of deep suture ligatures during attempts to control such bleeding. The placement of sutures should be limited to tacking the vessel to the surrounding levator muscle with a 3-0 or 4-0 absorbable stitch under direct vision. Deeply placed stitches in this location can cause unseen injury to the ipsilateral neurovascular bundle or continence mechanism.

As described in the previous two editions of this text, in order to avoid traction injury to the cavernosal nerves during apical retraction of the gland, we have used a modified approach to the nerve-sparing technique of Walsh. Following division of the deep dorsal venous complex, the lateral prostatic fascia is identified on the anterolateral aspect of the prostate (Fig. 42.3A). The prostatourethral junction is developed by bluntly pushing the overlying levator fibers off the apex with a Kitner dissector. The fascia is incised while it is elevated from the prostate capsule with a right-angle clamp. Care should be exercised to avoid injury to the prostate capsule during this maneuver. Once incised, the lateral edge of the incised fascia is lifted away from the gland and a plane is developed between the prostate and the lateral prostatic fascial contents (inclusive of the cavernosal nerve bundle). The plane is developed with blunt and sharp dissection along the prostatic apex and the prostatourethral junction. In this fashion, the nerve is completely freed from the prostatic apex before division

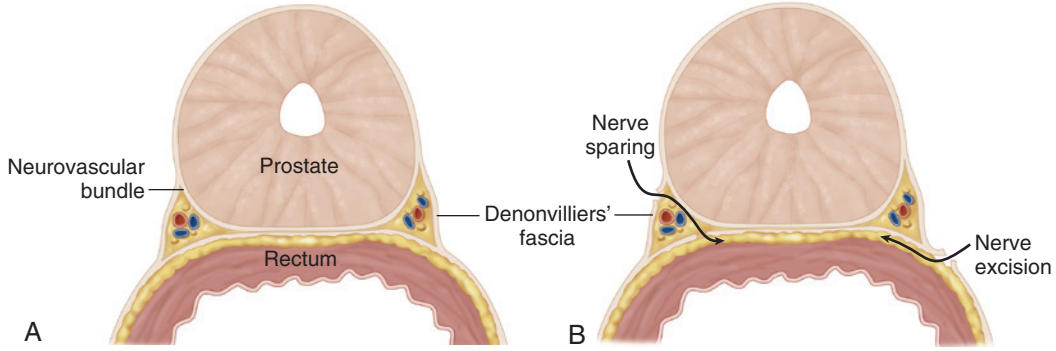


Figure 42.3 The neurovascular bundle dissection can be carried out for either preservation or wide excision. A, Anatomically, the neurovascular bundle is carried and is separated from the prostate by decussation of the lateral prostatic fascia and from the rectum by Denonvilliers' fascia. The lateral prostatic fascia extends over the lateral rectum dorsal to the position of the neurovascular bundles. B, In nerve preservation, the lateral fascia is released on the anterolateral surface of the prostate and then is rolled off the posterolateral aspect of the gland until Denonvilliers' fascia is exposed. On release of the neurovascular bundle, an incision in the posterior layer of Denonvilliers' fascia overlying the anterior rectal wall allows complete separation of the prostate from the bundle. Entry into the plane posterior to Denonvilliers' fascia allows elevation of the prostatic apex from the rectum such that no tension is placed on the nerves after division of the urethra and retraction of the prostatic apex. (Modified from Goad JR, Scardino PT. Modifications in the technique of radical retropubic prostatectomy to minimize blood loss. Urol Clin North Am. 1994;2:75.)

of the urethra or retraction of the prostatic apex (see Fig. 42.3B).

The plane between the lateral prostatic fascia and the prostate should develop easily with a blunt sweeping motion, but occasionally sharp dissection is necessary. On lateral reflection of the fascia from the posterolateral prostate, exposure should be medial to the neurovascular bundle to allow perforation of Denonvilliers' fascia and entry into the perirectal space (see Fig. 42.3B). Carrying the plane circumferentially around the prostate can make division of the posterior urethra and rectourethralis quite simple. Occasionally, the plane is adherent, and in this circumstance consideration should be given to the possibility of extraprostatic cancer advancement or simply residual fibrosis from the prostate biopsy. In these cases, the posterior plane should be developed following division of the urethra, and one should consider intraoperative frozen sections from the lateral and apical margin bed.[62]

Much attention has been focused on penile rehabilitation using behavioral and medical therapy to increase likelihood of potency following RRP. There is increasing evidence that smooth muscle atrophy may occur during the process of nerve regeneration. Animal studies have shown that the use of phosphodiesterase inhibitors preserves smooth muscle function following iatrogenic trauma to the cavernous nerves.[63] The controversy is whether similar efficacy is achieved with daily or on-demand phosphodiesterase inhibitors. Numerous authors reported significantly improved potency using phosphodiesterase-5 inhibitors following radical prostatectomy employing both on demand regimens as well as daily administration, immediately after the procedure, and continuing during the postoperative period.[64,65] At our institution, we routinely prescribe daily sildenafil 50 mg or tadalafil 5 mg for the first year postoperatively for these patients. We believe that sexual intimacy may also "atrophy" during the recovery of erectile function. Therefore we recommend early intervention with intracavernous injections in couples motivated to resume sexual intercourse.

INCONTINENCE

Incontinence remains the most feared and frustrating complication of radical prostatectomy for both patient and surgeon. Although contemporary surgical series report markedly improved rates of total continence compared with earlier series, a small percentage of cases still result in debilitating incontinence for the patient. Further underscoring the frustrating nature of the complication is the absence of any reliable preoperative or intraoperative predictors of postoperative continence.[66]

Contemporary surgical series report rates of continence ranging from 80% to 97%.[2,4,6,16,38,67–69] The definition of continence is variable likely due to surgeon experience and technique. The definition of continence should not be total continence since 14.2% of men report some degree of urinary leakage preoperatively.[66] Lepor and Kaci correlated responses to validated questionnaires assessing level of postprostatectomy continence and patients, self-assessment of continence.[66] At 2 years following surgery, 100% of men who reported occasional urinary leakage, or using a single protective pad over 24 hours, considered themselves continent. Therefore it is reasonable to use this definition of continence but requires careful explanation and counseling to men preoperatively to reinforce this definition of continence. Age may also influence continence. Catalona and colleagues[4,6] reported a 96% rate of continence in men <70 years old compared with a rate of 87% among those >70 years old. In contrast, however, Lepor et al. did not observe a significant correlation between age and restoration of continence.[16] Once again, the reports of incontinence rates are generally from centers of excellence in radical prostatectomy, and community-based series often report lower rates of total continence.[1,38–40,57,58]

The influence of nerve sparing upon continence remains controversial. Marien and Lepor examined return of continence in 1110 potent men in their longitudinal prospective outcomes study and reported no relationship between extent of nerve sparing or potency restoration with continence rates.[70]

In attempting to minimize the risk of incontinence in the postoperative setting, preservation of the external striated sphincter is of paramount importance. Minimizing the blind passage of clamps, periurethral dissection, and aggressive hemostatic suturing in the area of the external sphincter is critical for preservation of the sphincter. For this reason, we prefer to perform the apical dissection sharply with no passage of clamps. All suture ligatures are placed directly under vision, and no excessive efforts are made to control venous oozing in the periurethral area.

As described in the previous two editions of this text, following division of the dorsal venous complex as described, the membranous urethra is exposed. By leaving the puboprostatic ligaments largely intact, the normal suspension of the urethra to the symphysis is preserved. There is increasing evidence that continence is related to urethral length. Efforts should be made to maximally preserve the full thickness of the "spongy" tissue of the urethra along with its surrounding sheath. This goal is accomplished by limiting anterior sharp dissection to the point at which the catheter can first be palpated. This palpation allows precision in this incision and presents a distinctive advantage of open radical prostatectomy. Thinning of the anterior urethra, a potential pitfall of our technique of dorsal vein division, is avoided in this fashion.

As described, we perform our nerve-sparing procedure before division of the urethra. On completion of the procedure, the nerve bundles have been released from the posterolateral aspect of the prostatourethral junction. With gentle retraction on the prostatic apex, the lateral urethra is exposed, and division of the urethra is begun 5 mm distal to the prostatourethral junction (Fig. 42.4). The anterior two-thirds of the urethra are divided, exposing the catheter below. The anterior and lateral anastomotic sutures are placed at this time to incorporate urethral sponge and mucosa in each suture pass. Next, once the catheter has been divided, the posterior urethra is exposed. We believe that passage of the posterior sutures is best performed at this time to facilitate inclusion of the rectourethralis and urethral mucosa in the suture passage. Because the neurovascular bundle on either side of the urethra has already been released, passage of the posterior anastomotic sutures is possible at this point.

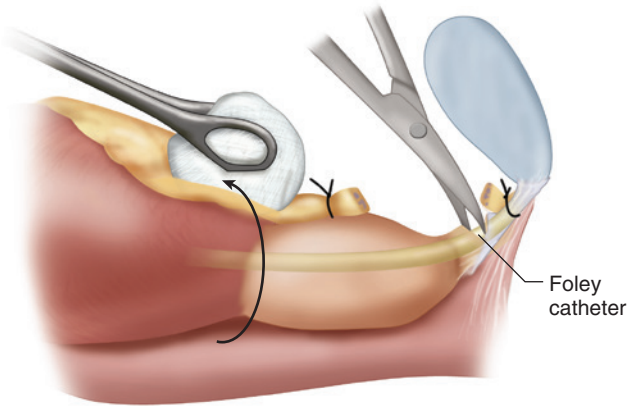


Figure 42.4 Division of the membranous urethra. The urethra is divided anteriorly following full release of the neurovascular bundles. Care is taken to preserve the full thickness of the urethra by cutting through the wall in a single stroke rather than layer by layer. In this fashion the urethral catheter is exposed. (From Tareen B, Godoy G, Taneja SS, Complications of Radical Retropubic Prostatectomy, in Complications of Urologic Surgery: Prevention and Management, 4th Edition, Taneja SS (ed), Saunders Elsevier, Philadephia, PA, 2010.)

When the surgeon assesses the patient with incontinence postoperatively, a careful historical evaluation should be performed to determine the nature of the incontinence. As discussed later, preexisting detrusor hypertrophy, instability, and decreased bladder wall compliance may contribute to postoperative voiding dysfunction. On occasion, these conditions can result in urge-related incontinence. The management of stress urinary incontinence following radical prostatectomy is discussed in Chapter 50. In general, surgical treatment of stress incontinence should be withheld until conservative treatment has failed for 10–12 months. In cases of severe incontinence lasting ≥6 months, complete resolution of incontinence is unlikely, and earlier intervention may be considered.

BLADDER NECK CONTRACTURE/ ANASTOMOTIC STRICTURE

Bladder neck contracture or vesicourethral anastomotic stricture is not an uncommon complication of radical prostatectomy; it occurs in 0.5–17.5% of cases.[4,20,52,68,71–73] The definition of an anastomotic stricture is variable. Some experts do not consider an "anastomotic obstruction" that is effectively managed by a single dilation to be a stricture. In most series, if anastomotic stricture is defined as any requirement for dilation, the rate is approximately 5–10%. This complication usually manifests within 3 months of catheter removal.[73] Anastomotic strictures may develop in men who undergo a technically flawless procedure associated with an uneventful recovery. There is some evidence that a subset of men who develop increased scarring of the surgical incision are predisposed to develop anastomotic strictures suggesting there may be genetic predisposition to scarring when the skin or bladder/urethra are approximated.[72] On occasion, late bladder neck contractures are noted, and consideration to the diagnosis should be given whenever patients complain of worsening incontinence, increased urgency or frequency, or decreased urinary stream.

Multiple factors may contribute to early contracture of the anastomosis including anastomotic urinary extravasation, poor mucosal approximation, suture reaction, and ischemia. A large review from the Cancer of the Prostate Strategic Urologic Research Endeavor (CaPSURE) database showed that men who developed stricture were older and had a higher body mass index.[71] Another report suggested increased postoperative blood loss predisposed to anastomotic stricture formation.[73] Although these factors are self-explanatory, some, such as ischemia and poor mucosal apposition, may not be easily recognized postoperatively. Attention to these issues is most important intraoperatively during completion of the anastomosis. Excessive thinning or mobilization of the bladder neck, particularly when rolling an anterior bladder wall tube, can cause ischemia and should be avoided. Sutures with nonreactive characteristics such as the absorbable monofilament poliglecaprone 25 (Monocryl) should be used.

Up until recently, many surgeons advocated mucosal apposition to decrease risk of anastomotic stricture. This led to tapering of the bladder neck with a mucosal everting stitch to avoid stricture in the tapered segment of the bladder neck. Anastomotic sutures can be positioned in the lumen of the bladder neck for further eversion of the mucosa to maximize mucosal apposition at the anastomosis. None of these efforts to evert the bladder mucosa is performed during robotic radical prostatectomy, without any evidence of increased incidence of anastomotic strictures. In fact, it has been suggested that an advantage of the robotic approach is a lower incidence of anastomotic strictures.[74] During the robotic approach, little effort is made to narrow the bladder neck. Stricture rates following open radical prostatectomy approach that of the robotic approach if bladder neck reconstruction is minimized.[75] We continue to evert the bladder neck mucosa for hemostasis and not to influence anastomotic stricture rates.

MINOR COMPLICATIONS

Inguinal hernia is another proposed complication of RRP, with a proposed incidence of 10–20%.[76,77] The cause has been elusive and has led many investigators to speculate that a lower midline incision in and of itself is the reason for the increased incidence of inguinal hernias. Stranne and colleagues[77] compared a survey population of various lower midline procedures versus a nonoperated group of patients and found significant differences in incidence at 24 months for development of inguinal hernia. Lepor and Robbins[78] reviewed 1300 patients undergoing RRP and showed a 13% incidence of inguinal hernias in this population, a finding suggesting that underdiagnosis of hernia on the preoperative examination was the likely reason for previously higher reported rates of postprostatectomy inguinal hernia. By repairing these clinical hernias at the time of radical prostatectomy using a preperitoneal approach,[26] these investigators found the postoperative incidence of hernias to be only 8%.[78] The question remained whether these hernias were caused by the open surgical approach or were they present but not detectable on physical examination. Valsalva MRI and upright transinguinal ultrasonography have been shown to detect clinically occult hernias.[79] If hernias are identified using Valsalva MRI inguinal ultrasound, the incidence of postprostatectomy hernias is reduced to <1%.[80] Therefore open radical prostatectomy does not cause hernias but rather transforms clinically insignificant hernias to clinically discernable hernias.

Urine loss during sexual intercourse or ejaculation is an often-overlooked complication of RRP. Studies often focus on volume of urine loss and correlate this with greater bother and more significant lifestyle changes.[81] Abouassaly and Gill and their colleagues[82] described their experience with postprostatectomy ejaculatory urine loss in 26 patients and reported that although the amounts of urine lost were typically small, they had a major impact on quality of life and led to a great deal of embarrassment and anxiety. Koeman and associates[83] were surprised to find that seven of 14 patients who complained of "weakened orgasm" in their series also complained of involuntary urine loss. In our experience, the incidence of climacturia decreases over time.[84,85] Men considered incontinence during sexual activity to be a major problem 22.4% and 12.1% of the time, at 3 and 24 months, respectively. In some cases, climacturia occurred independent of stress incontinence. Interestingly, when stress incontinence and climacturia co-existed, the climacturia often resolved following a male sling or artificial sphincter placement.[84,86–88] It remains unclear if climacturia will respond to similar surgical intervention if it occurs without stress incontinence.

Change in orgasm following RRP is another complication that is often not discussed with the patient or is lost when focusing on whether that patient will have potency. Other than the "dry orgasm," many patients believe that their orgasm is "weakened" or different in duration. One could hypothesize that lack of prostate and seminal vesicle contraction may contribute to this phenomenon.

The rate of *fecal incontinence* was reported to be ≤5% in men undergoing RRP who participated in a telephone survey in a study by Bishoff and colleagues.[88] Although rates of this complication are typically proposed to be higher in patients undergoing radical perineal prostatectomy, other investigators suggested that the rates of fecal incontinence noted by Bishoff and colleagues were considerably lower and that no significant differences existed between RRP and radical perineal prostatectomy in this regard.[87] A study of outcomes showed no difference between bowel symptoms in patients undergoing watchful waiting and those in patients undergoing RRP.[89]

Salvage Prostatectomy

Selection of candidates for radical prostatectomy following radiation can be difficult. In general, the operation results in relatively low rates of cancer control, although with proper selection, some investigators have reported 10-year clinical cancer-free survival rates of 60–70% and biochemical recurrence-free survival rates of 30–43%.[62,90,91] Investigators have estimated that as many as two-thirds of these patients have advanced pathologic disease (pT3a or greater).[39,62] Stephenson and Eastham[92] proposed that the 5-year progression-free rates for salvage RRP are 86%, 55%, and 28% for patients with preoperative prostate-specific antigen levels of 4 ng/mL, 4 ng/mL to 10 ng/mL, and >10 ng/mL, respectively.[62]

A higher likelihood of rectal injury is noted in patients undergoing salvage surgery than in those patients undergoing primary radical prostatectomy, with reported rates ranging from 6% to 15%.[39,40,93] Fibrotic reaction often ablates the plane posterior to the prostate, and to avoid injury to the rectum the surgeon should use sharp dissection to develop the plane. In patients with known proctitis or rectal devascularization resulting from radiation, strong consideration should be given to a diverting colostomy in the setting of rectal injury. In a properly prepared bowel, it may be acceptable to repair the injury primarily, but given the propensity for poor wound healing in the irradiated field, the surgeon should have a low threshold for proximal diversion. One option is to repair the defect primarily, but to raise a loop of sigmoid colon to a suprafascial position. If the rectum heals without difficulty, the loop can be dropped back into the abdomen and the fascia closed in a relatively

minor operation. If the rectal injury does not heal, a Turnbull-style loop stoma can be matured at the bedside.

In addition to intraoperative difficulty, individuals undergoing postirradiation prostatectomy are prone to higher rates of incontinence and deep vein thrombosis than are patients undergoing primary prostatectomy. Most groups report rates of incontinence >50%. For this reason, careful selection with regard to the possibility of cancer cure should be a fundamental tenet of salvage prostatectomy. We have not been strong advocates of the idea of palliative resection for locoregional control in this setting and believe that patient selection based on oncologic tenets is essential.

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Chapter 42 Questions

1. A 64-year-old man with a history of bilateral inguinal hernia repair with mesh as well as a history of diverticulitis undergoes open radical prostatectomy for a cT1c Gleason 3+4 prostate cancer. On digital rectal examination his prostate gland is approximately 50 grams in size. A preoperative multiparametric MRI demonstrates a significant intravesical lobe. During preparation of the dorsal vein complex (DVC) for ligation and division, he is found to have a significant anterior and retropubic gland. Which of the following maneuvers is most helpful as a next step?
   a. Straightening the operating table
   b. Wrap a tourniquet at the base of the penis to temporarily decrease blood flow to the DVC to assist division
   c. Catheter traction during DVC division
   d. Increase electrocautery current to 70 and attempt to coagulate the DVC stump
   e. Divide the puboprostatic ligaments to mobilize the prostate posteriorly

2. Which of the following are advantages of preoperative Epogen administration prior to undergoing open radical prostatectomy?
   a. Preoperative increase in hematocrit of ~10%
   b. Decreased rate of intraoperative blood loss
   c. Higher postoperative hemoglobin as compared to men donating preoperative autologous blood
   d. Earlier return of continence by 3% on standardized self-reported questionnaire
   e. Lower rate of allogeneic transfusion compared to men donating autologous blood preoperatively

3. A 56-year-old man with a BMI of 38 undergoes radical prostatectomy for a Gleason 7/10 prostate cancer. His surgery is uneventful, but on attempting reconstruction, the bladder neck will not reach the urethral stump. A Tanagho tube is constructed and allows for re-approximation and completion of the anastomosis. Which of the following delayed complications is he at higher risk for developing?
   a. Delayed return of urinary continence
   b. Erectile dysfunction
   c. Detrusor overactivity
   d. Anastomotic leak
   e. Bladder neck contracture

4. A 56-year-old man with a BMI of 28 undergoes radical prostatectomy for a Gleason 7/10 prostate cancer. His surgery is uneventful. Approximately 1 year following surgery he reports that he is voiding well and notes only occasional drops of urine when he drinks alcohol. He is able to achieve erections sufficient for intercourse when using PDE5 inhibitors. His PSA is undetectable. On routine examination, you note a reducible right inguinal hernia. Which of the following measures may have assisted in preventing the development of this inguinal hernia?
   a. Pfannenstiel incision
   b. Upright transinguinal ultrasonography
   c. Valsalva MRI
   d. b and c
   e. All of the above

5. A 65-year-old man with a history of DM, HTN and BPH is found to have Gleason 4+4 in 4/12 cores. He has a history of a cholecystectomy and his staging workup is negative. He undergoes an uncomplicated open radical prostatectomy. His final pathology demonstrates pT2cN0 Gleason 4+4 prostate cancer with negative margins. His catheter is removed on postoperative day 10. Two weeks later he reports fluid leakage per rectum. He denies fevers, chills, nause, or vomiting. What is the appropriate next step in his management?
   a. Low residue diet
   b. Begin empiric therapy for *Clostridium difficile* colitis
   c. Insert a urethral catheter
   d. Pelvic exploration, washout, and diverting colostomy
   e. a and c

6. Which of the following surgical steps should be avoided in order to minimize long-term impact upon urinary continence?
   a. Aggressive hemostasis of venous ooze in the periurethral tissue
   b. Sharp division of the urethra
   c. Maintain puboprostatic ligaments
   d. Place anterior anastomosis sutures under direct vision, following division of anterior urethra
   e. Maximal preservation of urethral tissue

Case Study 1

A 52-year-old man with a history of hyperlipidemia and hypothyroidism is found to have a PSA of 3.7 ng/mL when he applies for life insurance. He reports at initial evaluation that he experiences nocturia ×1, has some decreased erectile function, and does not use PDE5 inhibitors. He is otherwise satisfied with both his urinary and sexual function. He undergoes a prostate biopsy that demonstrates Gleason 3+4 in 2/12 cores.

He elects to manage his disease by undergoing an open radical prostatectomy with bilateral pelvic lymph node dissection. The case is uncomplicated with an estimated blood loss of 550 mL. Due to a prominent intravesical lobe, the bladder neck is tapered using an anterior tennis racket approach. His bladder neck mucosa is everted. Following completion of the anastomosis, irrigation demonstrates no leak. His postoperative hematocrit slowly drifts down and he requires 2 units, postoperative transfusion. His pelvic drain output increases on postoperative day 2.

1. Which of the following is the likely cause of his anastomotic leak?
   a. Bilateral nerve sparing
   b. Urethral length
   c. Intraoperative blood loss
   d. Bladder neck repair
   e. Postoperative blood loss

2. What is the next step in managing this leak?
   a. CT abdomen and pelvis
   b. Initiate total parenteral nutrition
   c. Re-exploration and correction of leak
   d. Continued catheter and monitoring of drain output
   e. Placing the catheter on gentle traction

3. On postoperative day 4 his catheter falls out during ambulation. What is the next management step?
   a. Suprapubic cystotomy
   b. Attempt gentle replacement of catheter
   c. Trial of void
   d. Flexible cystoscopy
   e. Re-exploration

4. The patient's catheter is replaced, and approximately 1 week later his drain output remains high. He undergoes a cystogram that demonstrates no evidence of extravasation from his vesicourethral anastomosis. He then undergoes a CT urogram that demonstrates a partial transection of his left ureter and concomitant urine leak. There is mild hydronephrosis. What is the next best management step in this setting?
   a. Continued observation
   b. Retrograde stenting
   c. Percutaneous nephrostomy
   d. Immediate ureteral reimplantation
   e. Nephrectomy

Answers

1. **e.** Routine division of the puboprostatic ligaments is not recommended. However, for situations where the prostate gland may be anteriorly displaced (via size or prior scar as is possible in this case), incision of the puboprostatic ligaments may drop the gland posteriorly and facilitate distal control. Restricting division only to the region needed to obtain improved access to the DVC is recommended as preservation of the ligaments prevents vein stump retraction and further assists in control.
2. **c.** Preoperative Epogen administration for 7–14 days in men with a preoperative hematocrit <48% results in an increase in the hematocrit of 3%. This approach resulted in a higher postoperative hemoglobin for those receiving Epogen as compared to men who donated autologous blood, while demonstrating no short- or long-term negative effects on cardiovascular or oncologic safety.
3. **e.** Bladder neck shortening is a problem most commonly encountered when wide resection of the bladder neck is carried out. A Tanagho tube refers to anterior relocation of the bladder neck opening by incising laterally on either side (3 and 9 o'clock) and then tapering posteriorly (6 o'clock). This creates a more anterior urethral or bladder neck attachment, thereby removing tension through increased bladder mobility. Anterior bladder tubes such as this risk ischemia to the mucosa and the anastomosis, thus increasing the risk of bladder neck contracture. Obesity is a separate risk factor for bladder neck contracture.
4. **d.** Open radical prostatectomy, like many lower abdominal surgeries, has been correlated with inguinal hernia development, although a cause has not been elucidated. Routine use of preoperative upright transinguinal ultrasound or Valsalva maneuver to identify occult preoperative inguinal hernia allows for repair at the time of prostatectomy, which has been reported to reduce incidence of postprostatectomy hernia to <1%. Open radical prostatectomy can be performed through a Pfannenstiel incision; however, this has not been shown to decrease rates of inguinal hernia postoperatively.
5. **e.** Unrecognized rectal injury presents the greatest risk of rectourethral fistula outside of salvage prostatectomy. Injuries most commonly occur during apical dissection and may be unrecognized if hemostasis is inadequate during this dissection. If a rectourinary fistula does develop and the patient is otherwise well, an initial attempt at conservative management can be attempted using bladder drainage and a low-residue diet. Complicated cases or patients with a history of radiation will likely require use of a temporary diverting colostomy.
6. **a.** Preservation of the external striated sphincter and surrounding tissue is of critical importance in preserving continence. Efforts to limit dissection in the periurethral tissue, including aggressive hemostasis of the periurethral bleeding veins, risk damage to the sphincter and surrounding innervation. During open radical prostatectomy, palpation of the urethra enables the incision on the urethra to be as close to the prostate as possible, thereby maximizing urethral length. Nerve sparing should be completed prior to urethral division to further assist in lateral urethral dissection and division, further preserving urethral length.

CASE STUDY 1

1. **e.** While an intraoperative evaluation of the anastomotic integrity may serve to allay surgeon concerns, early anastomotic integrity has been shown to be independent of the degree of intraoperative urinary extravasation noted. Anastomotic healing appears to be related to postoperative hematoma. Achieving hemostasis is the primary factor influencing the integrity of the anastomosis.
2. **d.** Conservative management of his urethral anastomosis at this time is recommended as he likely developed a post-operative pelvic hematoma that resulted in a distraction in his anastomosis. With continued catheter drainage, the leak will likely close.
3. **d.** In the early postoperative phase, it is usually reasonable to allow the patient an attempt at voiding. However, in this situation, given the anastomotic leak, it is best to perform a catheter replacement using a cystoscope. At this stage this can be attempted without anesthesia, but if available anesthesia will minimize patient discomfort and optimize likelihood for catheter replacement.
4. **c.** Ureteral injury during radical prostatectomy is rare. However, the risk for injury is greater when performing bladder neck division and reconstruction or when performing extended lymphadenectomy (above the iliac bifurcation). Techniques to aid in avoiding ureteral injury include employing indigo carmine intraoperatively or cannulating the ureteral orifices with feeding tubes at the time of anterior bladder neck division.

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SECTION VIII

Complications of Reconstructive Surgery

43 Complications of Ureteral Reconstructive Surgery

MITCHELL HUMPHREYS and SEAN MCADAMS

CHAPTER OUTLINE

Surgical Anatomy
Etiology and Epidemiology of Ureteral Injury
Diagnosis and Preoperative Planning
General Surgical Considerations
Surgical Management
Ureteroureterostomy
Ureteroneocystostomy (Ureteral Reimplant)
Vesicopsoas Hitch (Psoas Hitch)
Boari Bladder Flap
Renal Descensus (Nephropexy)
Buccal Mucosal Graft for Ureteroplasty
Transureteroureterostomy
Intestinal Interposition (Ileal Ureter)
Autotransplant
Ureteroenteric Anastomotic Stricture
Transplant Anastomotic Stricture
Ureterolysis
Postoperative Stenting and Drainage
General Complications and Management
  Urine Leakage
  Ureteral Stricture
Chapter 43 Questions and Answers

KEY POINTS

1. The ureteral blood supply to the proximal and midureter branches medially from the renal, aortic, gonadal, and lumbar arteries, while the pelvic ureter is perfused laterally from iliac branches.
2. Antegrade and retrograde ureteral imaging are needed to define the location and length of proximal and midureteral strictures. Bladder capacity should be measured preoperatively when psoas hitch or Boari bladder flap are being considered.
3. Surgical exploration may reveal less viable ureter than expected. Surgeons must be prepared to use additional maneuvers or alternative procedures to provide a tension-free anastomosis. These include vesicopsoas hitch, the Boari bladder flap, and downward nephropexy.
4. Early anastomotic strictures after renal transplant or urinary diversion are typically ischemic in nature. Endoscopic interventions for strictures >2.0 cm are unlikely to be successful, and ureteral reimplantation is an appropriate initial intervention.
5. Iatrogenic thermal injury from vessel sealing devices may have a delayed presentation. If diagnosed acutely, thermal injuries should be managed with excision of the ureteral segment with 1 cm margins prior to repair.
6. An indwelling ureteral stent should be left for all ureteral reconstructive procedures, as well as external drainage to monitor for anastomotic leakage.
7. Transureteroureterostomy is contraindicated in recurrent stone formers or in patients with history of urothelial carcinoma of the ureter or renal pelvis. The donor ureter should travel above the level of the inferior mesenteric artery to avoid impingement. Ureteral stent should travel from the bladder to the donor ureter.
8. Complete ureteral strictures can be bridged with a combination of Boari bladder flap and downward nephropexy. Ileal ureter and renal autotransplant are alternatives, though nephrectomy should be reserved for kidneys with relative function <15%.
9. Absorble suture should be used for a psoas hitch procedure with care taken to avoid entrapment of the femoral or genitofemoral nerves. Symptoms of nerve entrapment may resolve when suture dissolves.
10. Ileal ureter is contraindicated in patients with Cr of 2.0 mg/dL or greater, or with history of inflammatory bowel disease, radiation enteritis, or intestinal absorption disorders.
11. Reconstructive surgery of the ureter has entered the era of robotics with similar efficacy to open procedures in the hands of experienced surgeons. Surgical approach should be determined based on patient interests and surgeon skill set.

Reconstructive surgery of the ureter may be necessitated through trauma, cancer, recurrent stone disease, iatrogenic injury, or congenital abnormalities. The goals of ureteral reconstruction are to restore continuity, resolve obstruction, and preserve renal function while minimizing morbidity. Given that the ureter travels a significant distance through the retroperitoneum, there is variance in the management of injuries at different locations, and surgeons must understand the diverse reconstructive techniques.

This chapter reviews the surgical anatomy of the upper and lower ureter, the etiology of ureteral injury, provides a framework for procedures to consider depending on the type and location of the ureteral pathology, and discusses preoperative and intraoperative considerations and the identification and management of intraoperative and postoperative complications. Complications arising from iatrogenic ureteral injury are additionally covered in detail in Chapter 14, while complications arising from traumatic injuries of the ureter are reviewed in Chapter 15. While it is not possible to detail all reconstructive surgeries, the tenets of successful ureteral surgery will be discussed with regard to the most commonly employed procedures. Robotic-assisted laparoscopic ureteral reconstructive procedures are detailed in Chapter 35. In the current era, each of the discussed procedures has been performed laparoscopically and robotically and considerations unique to these approaches will be noted.

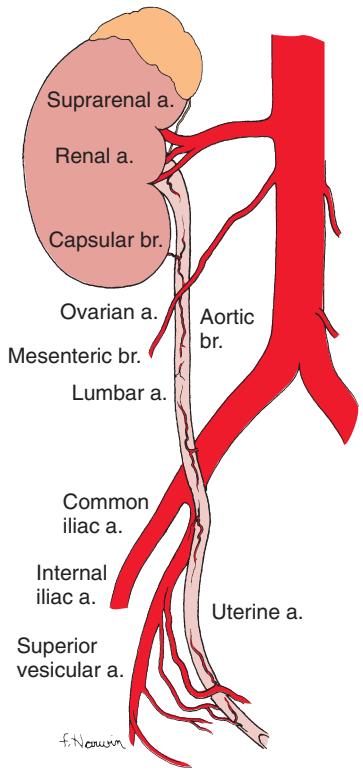


Figure 43.1 Blood supply of the ureter. Perforating arterial branches to the upper ureter emanate medial to the ureter, whereas those to the lower ureter emanate laterally. (From Smith RB, Skinner DG, eds. Complications of Urologic Disorders. Philadelphia: WB Saunders; 1976:131.)

Surgical Anatomy

The length of the ureter is typically 22–30 cm, with a normal luminal diameter of 1–3 mm, depending on its location[1,2] The three areas of physiologic narrowing are the ureteropelvic junction (UPJ), the crossing over of the bifurcation of the iliac arteries, and the ureterovesical junction (UVJ). Ureteral injuries can occur throughout the entire length of the ureter, though the proximal ureter may be more prone to severe injury or disruption since it has less muscular support and fewer mucosal cell layers than the distal or intramural ureter.

Starting from the kidney, the ureter lies posterior to the hilar vessels. As it travels caudally, the ureter courses posterior to the gonadal vessels and anterior to the iliopsoas muscle, then crosses the bifurcation of the common iliac artery as it enters into the pelvis. The pelvic ureter comprises the distal one-third of the ureter. Here the peritoneum is adherent to the ureter anteriorly. In males, the vas deferens loops anterior to the ureter, prior to the ureter entering the bladder. In females, the ureter courses posterior to the uterine arteries found in the broad ligament, running approximately 2 cm lateral to the uterocervical junction and then closely approximates the vagina prior to reaching the intramural bladder.

Ureteric arteries and arterioles travel longitudinally in the adventitia of the ureter. The blood supply to the proximal and midureter branches medially from the renal, aortic, gonadal, and lumbar arteries, while the pelvic ureter is perfused by branches laterally from the iliac artery and its branches (vesical, uterine, hemorrhoidal arteries) (Fig. 43.1).

Etiology and Epidemiology of Ureteral Injury

Understanding the mechanism of injury and patient factors is critical to conceiving a successful surgical approach. Ureteral injury or obstruction may result from urothelial cell cancer, nephrolithiasis, retroperitoneal fibrosis, radiation, infection (tuberculosis, schistosomiasis), blunt or penetrating trauma, or iatrogenic causes. Ureteral trauma is discussed elsewhere in this text. Strictures from urothelial cell cancer are typically managed by excision of the entire ureter and renal unit, and reconstructive procedures (most commonly partial ureterectomy with primary ureteroureterostomy or reimplant) are limited to low-grade distal ureteral lesions. Wolf et al. defined a stricture as ischemic when it follows surgery (e.g., hysterectomy) or radiation therapy, whereas the stricture is considered nonischemic if it is secondary to stone passage or a congenital abnormality. Ischemic strictures tend to be associated with fibrosis and scar formation and thus are less likely to respond to endourologic interventions.[3] Long strictures may result from conditions such as tuberculosis, schistosomiasis, amyloidosis, malakoplakia, and leukoplakia,[4] making a thorough patient history and physical important to diagnosis and management.

Iatrogenic injury to the ureter has become more common with the increase in endourologic procedures and laparoscopic surgery. Contemporary expert series of ureteroscopic complications estimate a perforation rate of 1–5%[5] of

which 0.2% require open surgery, and an incidence of delayed stricture of up to 5%.[5,6] Ureteroscopic surgery is performed at such high frequency that it is currently the most common cause of iatrogenic ureteral stricture.

Ureteral injury, and its management, is discussed in detail in Chapter 14. The incidence of ureteral injury in contemporary series with colorectal or gynecologic surgery has been reported as between 0.1% and 7.6%, with over 80% of injuries being unrecognized at the time of procedure.[7] A Cochrane review found patients were nearly 2.5 times as likely to experience a ureteral or bladder injury with a laparoscopic hysterectomy compared to an open procedure.[8] With the da Vinci robotic surgical system (Intuitive Surgical, Sunnyvale, CA), ureteral injury has been found to occur in 1.7% of hysterectomy cases.[9] During hysterectomy, the ureter is most commonly injured during the ligation and transection of the uterine artery. Entrapment of the ureter may also occur with closure of the vaginal cuff.

Iatrogenic ureteral injury can result from electrocoagulation or ultrasonic instruments, staples, loop sutures, or trocars. When called into an operating room to assist in assessment for injury, it is important for the urologist to understand the mechanism and energy source of the injury. Loop sutures can often simply be cut or removed, whereas complete or partial transection from a thermal device will require more involved surgical management. Thermal damage may result from the steam generated from the application of electrical current, or from inadvertent contact with the ureter by a "hot" instrument. The injury effect may take days to develop, and thus recognition is typically delayed.

Intraoperative cystoscopy is useful to detect ureteral injuries such as entrapment and transection and facilitates immediate correction and potentiates avoidance of late morbidity. Gilmour found intraoperative cystoscopy identified about 90% of unrecognized ureteral injuries during gynecologic surgery, 69% of which were easily managed, most by simply removing a suture.[10] Methylene blue or 10% sodium fluorescein dye can be given to aid in cystoscopic evaluation of ureteral efflux, and retrograde pyelography or ureteroscopy can be confirmatory when there is concern for injury. Intraoperative cystoscopy may not be useful for detection of thermal damage or ischemia secondary to their typically delayed presentation.

Diagnosis and Preoperative Planning

The time to recognition of ureteral injury or stricture is variable and dependent upon the type and severity of the injury, ranging from days to weeks.[11] Patients with ureteral transections resulting in urine extravasation may present with a urinoma in the immediate days after surgery and can experience ileus secondary to chemical peritonitis. Ureteral entrapment may be asymptomatic or patients may present within 1 week with flank pain or possibly with fever due to pyelonephritis. Thermal injuries result in delayed tissue necrosis and may be diagnosed as long as 3 weeks after surgery. Ureteral strictures can take months to develop and thus may result in minimal symptoms or even cause asymptomatic "silent obstruction."[12]

Once an injury is recognized, thorough evaluation and careful surgical planning are paramount to successful repair. In most cases retrograde urography and attempted stent placement, utilizing ureteroscopy when needed, serve as first-line therapy. They provide understanding of the extent and level of the injury and aid in operative planning. When unable to place a retrograde stent, proceed with placement of a nephrostomy tube with antegrade urography and consider an immediate or delayed attempt at antegrade stent placement. External drains should be placed for fluid collection when a patient is symptomatic or when an infected urinoma is suspected. When injury presents in an otherwise stable patient within less than 1 week from the injury, immediate repair should be considered. If the patient is unstable, has evidence of infection, or if it has been greater than 1 week since the injury, delay of repair for 6 weeks is recommended to allow time for resolution of inflammation.

The function of each kidney and the anatomy of both ureters should be evaluated preoperatively. Preoperative nuclear renography assesses the relative function in the ipsilateral renal unit. If the relative function is less than 15% and the insult has been chronic, and/or the repair risks the contralateral renal unit, then nephrectomy should be considered. Patients undergoing ureteral reconstruction may have residual hydronephrosis and reflux after surgery, and having a preoperative renogram provides a functional baseline for monitoring treatment success and the need for additional intervention when postoperative imaging is equivocal. For proximal and midureteral strictures, ureteral anatomy is best defined with a combination of antegrade and retrograde contrast studies (Fig. 43.2). Chronic indwelling ureteral stents may cause artificial dilation of the obstructed ureteral segment. In our opinion, preoperative



Figure 43.2 Simultaneous antegrade and retrograde ureterography demonstrating a left midureteral injury from L4 to the pelvic brim with proximal hydroureteronephrosis. This injury resulted from emergent bowel surgery.

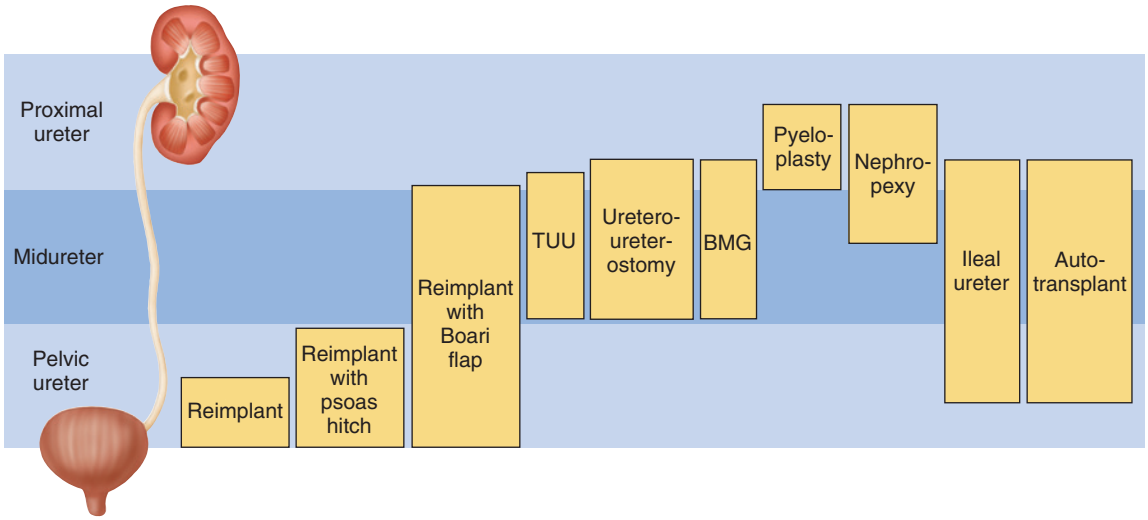


Figure 43.3 Options for surgical reconstruction of the ureter based upon the location of injury. TUU, transureteroureterostomy; BMG, buccal mucosa graft.

stent removal with nephrostomy tube substitution and repeat imaging after 1–2 weeks allow for resolution of artificial dilation and more accurate identification of stenotic segments. Since ureteral reimplant is most likely for pelvic ureteral injuries, antegrade ureterography or the delayed urography phase of a computed tomography (CT) scan provides sufficient information. Bladder capacity should be determined preoperatively if considering a bladder flap procedure, with alternative procedures considered for low-capacity bladders.

General Surgical Considerations

The surgical approach varies based upon location, mechanism of injury, medical history, and other patient factors. Fig. 43.3 provides an overview of options for surgical reconstruction on the ureter based upon the location of injury. Thoughtful planning of patient positioning, incision type, and wide draping for open procedures permits exposure to the entire ureter and renal unit if necessary. For laparoscopic and robotic procedures, a common pitfall is placement of the ports such that proximal dissection is limited. This can be an issue when unanticipated renal mobilization with nephropexy is needed, or when viable ureter is found to be more proximal than anticipated. Contraindications to elective ureteral reconstructive surgery include an untreated urinary tract infection or a bleeding diastasis.

The first intraoperative consideration when repairing the ureter is locating the area of ureteral injury. Urinary leakage and fibrosis can result in loss of normal tissue planes and medialization of the ureter. Generally, it is preferable to locate the ureter distally or proximally to the injury in an area with normal tissue planes, encircle it, and follow the ureter to the area of injury. If a nephrostomy tube is in place, antegrade fluid injection can aid in identification. The next important consideration is the mechanism of injury. For example, the majority of gynecologic injuries occur to the distal ureter. In such cases we identify the ureter entering the pelvis when traveling anterior to the common iliac vessels. The injury will almost always be distal to this location. In all cases, known landmarks should be utilized for ureteral identification.

Excessive mobilization or mishandling of the ureter can result in ischemia and necrosis or ureteral stricture. When reconstructing devitalized ureter, it is critical to only include viable ureter in the anastomosis. Devitalized ureter can be identified by pallor, friability, thick periureteral scarring, and lack of bleeding from the cut edges. Box 43.1 lists the tenets of successful ureteral reconstructive surgery that apply to all procedures detailed in this chapter, regardless of approach.

Box 43.1 Tenets of Ureteral Reconstructive Surgery

- Preserve the native ureteral blood supply (adventitia) by careful mobilization.
- Debride edges of injured ureter until bleeding noted; do not compromise, and be prepared to perform any number of reconstructive procedures.
- Spatulate the ureteral edges to achieve a widely patent anastomosis.
- Mucosa-to-mucosa apposition is critical for optimal healing and reducing the risk of urine leak.
- The anastomosis should be tension free, water tight, and performed over a ureteral stent. Avoid ureteral torsion with the anastomosis or ureteral kinking from other structures.
- Use only absorbable suture within the urinary tract to avoid risk of calcification seen with permanent suture.
- Isolate the repair from processes of infection or fibrosis with (omental) tissue flaps.
- Place an external drain at the operative site to monitor and control any potential urine leak.

Surgical Management

URETEROURETEROSTOMY

Ureteroureterostomy (UU) is utilized for short upper and midureteral defects that are 2–3 cm long or shorter

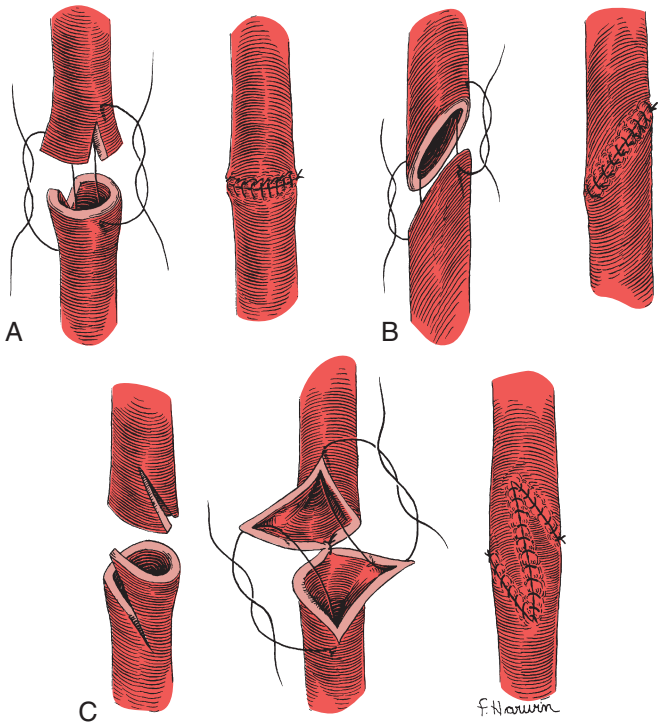


Figure 43.4 Ureteroureterostomy: techniques to maximize luminal diameter. A, Spatulation of ureteral margins. B, Oblique anastomosis. C, Z-plasty technique. (From Smith RB, Skinner DG, eds. Complications of Urologic Disorders. Philadelphia: WB Saunders; 1976:137.)

strictures that have failed endoscopic intervention. It is critical to have a tension-free repair with UU to avoid stricture formation. The determination of whether the ureter can be sufficiently mobilized after excision of the diseased portion to perform a tension-free UU cannot be made until the time of surgery. Concomitant renal mobilization with nephropexy can help reduce anastomotic tension. The location of the stricture will guide the surgical skin incision or port site placement for laparoscopic procedures, bearing in mind that the ureter will need to be mobilized both proximally and distally. After debridement of nonviable tissue, each ureteral segment is spatulated for approximately 5 mm, at 180 degrees apart. Fig. 43.4 demonstrates anastomotic techniques to maximize luminal diameter. Success rates greater than 90% are reported for open surgery[13,14] Lee et al. reported success in 11 of 12 patients undergoing robotic UU with concurrent nephropexy at a mean of 10 months' follow-up for a mean stricture length of 2 cm.[15]

URETERONEOCYSTOSTOMY (URETERAL REIMPLANT)

Ureteroneocystostomy indications include vesicoureteral reflux, distal ureteral obstruction, and transection involving the distal 3–4 cm of the ureter. Both refluxing and nonrefluxing methods exist and extravesical and intravesical surgical approaches have been defined. In a retrospective review of adults undergoing reimplant, no significant difference in preservation of renal function or subsequent stenosis was identified between refluxing and nonrefluxing techniques.[16] The efficacy of laparoscopic and robotic reimplant is well established[17] and has been associated with reduced blood loss and hospital stay.[18] Due to the common adoption of robot-assisted prostatectomy, many urologists are comfortable performing this procedure robotically given the similar setup and familiar pelvic anatomy. Compared to prostatectomy, robotic ports are typically shifted slightly cephalad.

VESICOPSOAS HITCH (PSOAS HITCH)

The psoas hitch procedure involves mobilizing the urinary bladder toward the ipsilateral ureter and securing the bladder to the ipsilateral psoas tendon, with a goal of shortening the needed ureteral length and reducing tension on the ureterovesical anastomosis. The technique is most commonly used for reimplantation after injury or excision of the distal one-third of the ureter and can be used to bridge defects of up to 6–8 cm. Psoas hitch may also be used in conjunction with other maneuvers, such as Boari bladder flap or renal mobilization, when the viable ureter is more proximal. Relative contraindications to psoas hitch include a fixed bladder secondary to a history of pelvic radiation, a contracted bladder, or untreated bladder outlet obstruction. Preoperative cystogram or cystometrogram may be helpful in determining bladder capacity.

Intraoperatively, the bladder is filled with approximately 200 mL of fluid. After bladder mobilization the surgeon should confirm the ability for the bladder dome to reach over the ipsilateral iliac vessels to the psoas muscle. The contralateral superior vesical artery may be sacrificed to aid in mobilization if necessary. An anterior cystotomy is then made, classically in the oblique direction. Alternatively, a transverse incision provides the flexibility of closing the bladder in a longitudinal (Heineke-Mikulicz) fashion to gain additional cephalad reach of the bladder. A traction suture on the distal ureter will help with ureteral delivery into the bladder with minimal manipulation to the ureteral tissue. The ureter should be delivered through a second incision at the superolateral aspect of the dome of the bladder and not to its orthotopic location to allow the straightest course for the ureter. The psoas hitch sutures are then placed and secured prior to completion of the anastomosis to reduce anastomotic tension. A minimum of two interrupted or figure-of-eight slowly absorbing sutures are placed into the bladder detrusor muscle and then superficially into the psoas muscle, including the psoas minor tendon when identified. All sutures should be placed before any are tied to reduce the risk of tearing the muscle or bladder when placing subsequent sutures. Over tightening of the hitch sutures can result in ischemia to the psoas muscle fibers.

The ureter is spatulated anteriorly, and the anastomosis is performed with interrupted 4-0 absorbable suture. The posterior ureter should be anchored with suture to the detrusor muscle. The remaining sutures should approximate bladder and ureteral mucosa and not include the detrusor muscle. Externally, the ureteral adventitia can be secured to the bladder wall with interrupted suture for additional reinforcement. The bladder is then closed in two layers to ensure watertight closure, and a Foley catheter is left in place for 7–10 days with a cystogram prior to removal.

Urinary extravasation is the most common complication and typically resolves with maximal urinary drainage and time. Injury to the femoral nerve or the genitofemoral nerve, though uncommon, can result from placement of the psoas hitch sutures. The femoral nerve runs deep within the psoas major muscle (PMM), emerging caudally to the typical location that a psoas hitch is anchored. However, on rare occasions, if the hitch sutures are placed too deep into the PMM, the nerve may become entrapped. Patients may present with leg weakness, gait difficulty, or complain of inability to climb stairs. On exam, reduced strength will be noted with hip flexion and knee extension. Additionally, decreased sensation of the anteromedial region of the thigh can be seen and the patellar reflex may be abnormal. If suspected, the diagnosis can be confirmed with neurology consultation and electromyogram. The genitofemoral nerve runs along the ventral aspect of the psoas muscle parallel to the ureter and is more commonly at risk for entrapment when placing hitch sutures. Symptoms of entrapment or destruction of this nerve are numbness to the ipsilateral anterior thigh and lateral scrotum in males, or mons pubis in females. In a small case series of femoral nerve injuries after psoas hitch, Kowalczyk et al. described eventual resolution of symptoms in patients in whom absorbable suture was used, but persistence of injury symptoms and the need to reoperate when nonabsorbable suture was used.[19] Physical therapy and early mobilization are beneficial when nerve injury is first suspected.

BOARI BLADDER FLAP

The Boari bladder flap (BBF) has been widely used for ureteral reconstruction for decades and is the next maneuver to consider when psoas hitch alone will not provide a tension-free anastomosis. BBF with psoas hitch can bridge a distance of 12–15 cm. The obvious advantage of this technique is that it does not endanger the contralateral renal unit or the intestinal tract, as do other reconstructive options. Also, its use is not limited by renal function, ileal disease, or recurrent stone disease. BBF is most commonly used for strictures involving the lower two-thirds of the ureter with success rates of 71–91%.[20,21] Morey et al. reported BBF success rates in 90% of 20 patients at 1 year in a series of both distal and proximal ureteral strictures, done in combination with nephropexy for proximal strictures.[22]

The bladder should first be mobilized and distended to identify the location and length of the bladder incision. Care must be taken to avoid injury to the ipsilateral middle and inferior vesical arteries that provide blood supply to the flap. To avoid ischemia the minimum width of the base of the flap should be 4 cm, with a goal of a 3:1 ratio of flap length-to-base width (Fig. 43.5). A rough measurement of the ureteral defect should be taken after debridement of nonviable tissue with subsequent marking of this distance on the bladder prior to incision. A U-incision is typically made but an L-incision allows a spiral flap when needed for longer defects. A psoas hitch at the base and the cephalad end of the Boari tube helps to stabilize the anastomosis.

The ureteral anastomosis can be executed as an end-to-end anastomosis to the tubularized flap, or by tunneling the implant into the posterior aspect of the flap, approximately 1 cm distal to the apex, prior to tubularization. While there is no evidence to support improved outcomes with a nonrefluxing anastomosis, this option avoids the intersection of the bladder closure suture line with the anastomosis and may reduce the risk of urinary extravasation. Two-layer closure of the tubularized flap is recommended and the previously mobilized peritoneum can be used to cover the anastomosis.

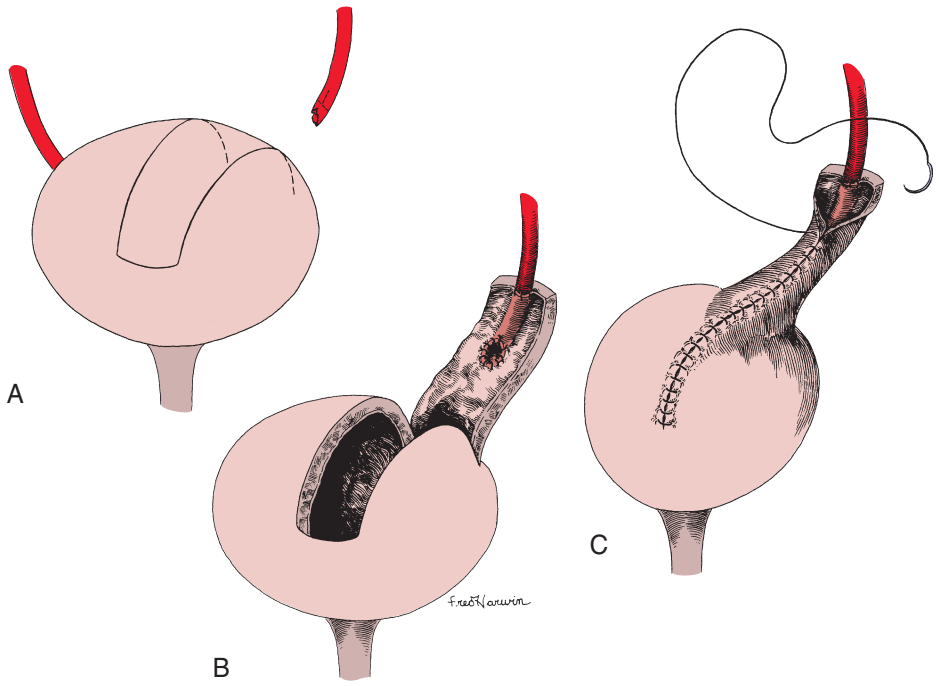


Figure 43.5 Bladder flap procedure. A, Creation of a tapered bladder flap, based posteriorly. B, Submucosal ureteral reimplantation. C, Closure of the bladder flap. (From Smith RB, Skinner DG, eds. Complications of Urologic Disorders. Philadelphia: WB Saunders; 1976:142.)

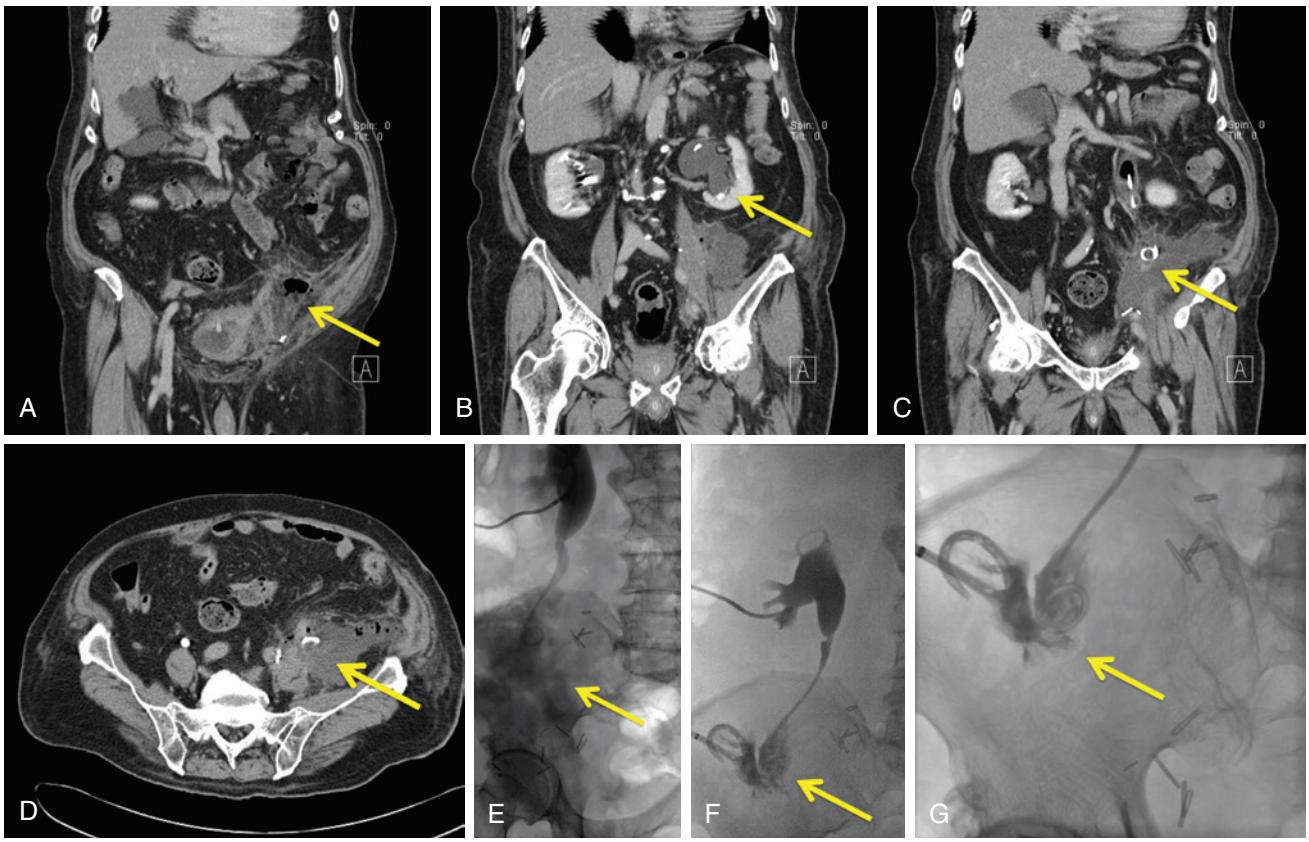


Figure 43.6 A 78-year-old male underwent a distal ureteral resection for a urothelial cancer isolated to the distal ureter. He presented with fever and worsening left lower quadrant discomfort 10 days postoperatively. He is noted to have leukocytosis and tenderness over the left lower quadrant. A CT urogram is obtained demonstrating (A) inflammation with fluid air surrounding the Boari flap (yellow arrow), (B) proximal left hydronephrosis (yellow arrow), and (C and D) the distal "j" of the ureteral stent in a large urinoma (yellow arrows). A left nephrostomy is placed, and antegrade nephrostogram (E) demonstrates free extravasation of contrast in the pelvis (yellow arrow). A percutaneous drain is placed in the urinoma (F and G) demonstrating the pigtail and distal stent to reside in the same cavity, without communication to the bladder flap (yellow arrows). (Courtesy of Samir Taneja, MD.)

Minimally invasive laparoscopic or robot-assisted techniques for BBF in the treatment of the middle and distal ureter have been reported with good results,[23,24] noting decreased blood loss and hospital stay[18] compared to open reconstruction. Such techniques are technically challenging for proximal or long ureteral strictures that require both the bladder and the kidney to be mobilized, but hybrid techniques such as laparoscopic mobilization of the kidney with open BBF and ureteral reimplant are available options. The da Vinci Xi system (Intuitive Surgical, Sunnyvale, CA) provides multi-quadrant access ability without the need for re-docking of the robot and may permit access to a greater span of the ureter compared to previous robotic systems.

Complications of BBF include bladder pedicle ischemia with resultant necrosis, stenosis of the bladder tube (flap), postoperative bowel obstruction, and urinary extravasation (Fig. 43.6). The incidence of complications is difficult to estimate, as contemporary series each include less than 20 patients[18,22–24] and list rates ranging from 8% to 25%. Injury to the contralateral ureter must be avoided during bladder mobilization or bladder defect closure. De novo irritative voiding complaints related to change in bladder capacity and configuration are reportedly rare and readily managed with anticholinergics,[22] but studies including postoperative urodyamic assessment are lacking.

RENAL DESCENSUS (NEPHROPEXY)

Renal descensus, or nephropexy, is employed as an adjunct to other procedures, namely to UU and BBF to eliminate anastomotic tension.[22] Nephropexy is commonly utilized with UU to bridge distances of 3–4 cm, though up to 8–10 cm of length can be obtained by completely mobilizing the kidney and affixing it to the iliac fossa. Caudal mobilization is limited by the anatomy of the renal vein, and thus greater mobilization is possible on the left. Mobilization includes dissection of the proximal ureter from its paraureteral tissue including perforating blood vessels. Sparing the perinephric and perihilar fat in the space formed by the upper ureter, renal artery, and the lower pole of the kidney typically ensures that the ureteral blood supply from the renal artery is maintained. Damage to this area, referred to as the "golden triangle" in transplant surgery,[25] leads to ischemia and may explain why 70% of transplant ureteral strictures occur in the distal third of the ureter.[26]

BUCCAL MUCOSAL GRAFT FOR URETEROPLASTY

Buccal mucosa is an excellent free graft due to a thin lamina propria with an abundant capillary network and

is commonly used by urologists in urethral reconstruction with excellent established long-term outcomes. The graft is harvested from the inner cheek or the inner lip, and graft lengths of 6 cm can be obtained. Buccal mucosal grafts (BMGs) for the repair of ureteral strictures have been described in several case series. This technique has utility for situations when an ileal ureter or autotransplant would otherwise be employed, namely for long proximal ureteral strictures. Several variants have been described, including dorsal or ventral onlay grafting and interposition of a tubularized segment with end-to-end anastomosis.

Unlike a flap, a graft is transposed onto new tissue without its native blood supply. Complications unique to a graft therefore relate to the ability to "take," or establish a new blood supply from surrounding tissues. Judicious debridement of the injured and ischemic tissue along with thinning or "defatting" the graft will increase the ability of the graft to take. An omental wrap is recommended to augment the vascularity and reduce the risk of ischemic complications such as stricture and dehiscence.[27] Graft contraction can occur, so it is recommended to make the graft size generous compared to the defect and then trim the graft as needed at the time of placement.

Another unique concern with this procedure comprises the complications and perioperative management related to the harvesting of the BMG. Care must be taken to avoid Stensen's duct (from the parotid gland) or harvesting tissue too close to the exterior lip as this can result in mouth contracture. BMG harvesting should be performed by urologists with experience in urethroplasty or by a maxillofacial surgeon. Morbidity in BMG harvest is minimal, with a complication rate reported at 3–4%.[28] The most common complications include donor site pain, scarring, perioral sensory defect, and jaw opening impairment.[29,30] Perioral numbness at 6 months has been reported in up to 26% of patients.[30]

TRANSURETEROURETEROSTOMY

Transureteroureterostomy (TUU) is a proven means to manage long-segment distal and midureteral disease or injury when reimplantation is not possible. TUU should be considered when psoas hitch with BBF is not an option due to an immobile bladder or the presence of a hostile pelvis. TUU requires a sufficient length of viable ureter to reach the contralateral ureter. As always, the surgeon and patient should be prepared for alternative (and more involved) interventions should the pathology extend more proximally than anticipated.

The inherent risk with TUU is exposure of both renal units if an anastomotic complication occurs or if obstruction occurs distally in the recipient ureter. For this reason, TUU is absolutely contraindicated in the presence of transitional cell carcinoma of the ureter or renal pelvis and in patients with recurrent urolithiasis, and should be avoided in those with a history of genitourinary tuberculosis, reflux or obstruction of the recipient ureter, severe chronic renal insufficiency, or recurrent pyelonephritis of either renal unit. The surgeon should be aware of ureteral duplication or other anomalies that may affect the approach.

The donor ureter should be sufficiently mobilized without compromising blood supply. A retroperitoneal tunnel is made to pass the injured (donor) ureter to the contralateral side. En bloc transfer of the ipsilateral gonadal vessel may improve the blood supply to the transposed ureter. It is important for the donor ureter to course gradually downward toward the recipient ureter to permit dependent drainage and when possible travel above the level of the inferior mesenteric artery to avoid impingement between the aorta and the inferior mesenteric artery. Such impingement can result in fibrosis and stricture and have a delayed presentation of obstruction as many as 2–4 years after surgery.[31,32] Mobilization of the recipient ureter site should be minimized to reduce trauma and preserve blood supply. A 1.5-cm ureterotomy is made on the recipient ureter and the donor ureter is spatulated 1.5–2 cm. The end-to-side anastomosis should be without tension, watertight, and should not cause torsion or angulation of the recipient ureter. The requisite urinary stent should travel from the bladder to the donor ureter so as to bridge the anastomosis. Alternatively, two smaller caliber stents (4.8Fr) can be placed up each proximal ureter and down the common ureter into the bladder. A postoperative KUB can confirm stent position.

Complications range from 6% to 25% in contemporary studies of open TUU.[32,33] Noble et al. reviewed 253 procedures performed at their institution for both benign and malignant diseases that affected the distal ureter. Transient leak occurred in 16 (6%) patients and there was a complication of the common ureter distal to the TUU in five patients.[34] Long-term follow-up of both renal units is mandatory given delayed presentation of stricture, and particularly if there is a possibility of the common ureter being affected by the process that caused initial insult (radiation fibrosis, pelvic malignancy, etc.).

INTESTINAL INTERPOSITION (ILEAL URETER)

Intestinal interposition is a proven technique for repair of extensive ureteral injuries when other reconstructive techniques are unable to be utilized for repair or in the case of salvage procedures after previous ureteral surgery. It may be favorable in cases of radiation-induced ureteral stricture disease since the vascular supply to the bowel tends to be preserved. While both colon and appendix have been utilized, ileum is the most common intestinal interposition. Historically the ileal ureter was utilized as a "stone chute" for recurrent stone formers. With advancements in endourology this is no longer a primary indication, but it does make ileal ureter a favorable choice in patients with a need for ureteral reconstruction and a history of nephrolithiasis.[35] The ileum can be configured in a "figure of seven" or "reverse 7" orientation for bilateral ureteral disease, or the appendix can be used as a substitution for the right ureter with use of the ileum on the left. Ileal ureter should be avoided in individuals with renal insufficiency and a serum creatinine >2 mg/dL due to the metabolic derangements that can result from urine resorption.[36,37] It is also contraindicated in patients with Crohn's disease, radiation enteritis, or intestinal absorptive disorders. Bladder emptying should be adequate to avoid bladder obstruction from mucus build up. Complete intracorporeal ileal ureter has been demonstrated laparoscopically[38] and robotically.[39]

Intraoperatively it is important to measure the length of diseased segment that will be replaced. The goal is to have a tension-free repair, with a straight ureter. Redundant

ureter can cause kinking and obstruction, leading to dilation and increased urinary resorption. It is ideal to minimize the length of ileum that is used because the bowel retains its absorptive properties. Thus, consider performing the procedure in conjunction with a Boari bladder flap and psoas hitch to shorten the segment of bowel that is required. It is advised to harvest a slightly more generous length than needed and subsequently trim the tissue rather than harvest too short of a length of bowel and be faced with an anastomosis under tension or the need to harvest a second segment. The terminal ileum should not be utilized as its exclusion from the gasterointestinal tract can result in B_{12} deficiency and malabsorption of bile salts. The bowel segment should be flushed to clear excess mucus and be connected in an isoperistaltic direction. Failure to do so could result in urinary stasis, ureteral dilation, and exacerbation of urinary reabsorption. The ileal ureter should be posterior to the bowel anastomosis, and on the left should pass through a defect in the mesentery into the retroperitoneum that is large enough (about 5 cm) to avoid ischemia to the mesentery of the ileal ureter. If viable ureter is present proximally and the patient is not a stone former, the ureter can be anastomosed to the ileal segment in an end-to-side fashion. Otherwise, the ileum is sewn directly to the renal pelvis. The distal anastomosis can be freely refluxing, as this has not been associated with renal deterioration.[36]

Success rates are reported at 81–100%.[36,37,40] Thirty-day minor complications (Clavien grade I–II) have been reported in upward of 40% of patients.[35] Notable long-term complications reported by Armatys et al. in 99 renal units[35] included a 3% anastomotic stricture rate and a 6% fistula rate. A history of radiation was cited as a risk factor for complication. Bowel obstruction is a complication more common to this procedure compared to other options for ureteral reconstruction and must be managed expectantly. Resorption of urine by the ileal segment can lead to a chronic worsening of renal function and hyperchloremic metabolic acidosis.[35] In two retrospective analyses patients did not experience worsening renal function after ileal ureter, and a third demonstrated serum creatinine decreased or remained stable in 75% of cases.[35,36,41] Long-term follow-up in these patients should include annual ultrasound, metabolic panel, and a B_{12} level. Patients presenting with recurrent pyelonephritis or worsening renal function after ileal ureter should be assessed for urinary retention or high pressure voiding and managed as needed.

AUTOTRANSPLANT

Renal autotransplant should be considered as one of the last options before nephrectomy for patients that have profound ureteral loss, have a solitary kidney or severe renal insufficiency, or have failed other attempts at repair. Indications are similar to ileal ureter; however, decreased renal function and history of inflammatory bowel disease are not a contraindication as with ileal ureter. Preoperative renal angiography (CT angiography) is necessary to delineate the vascular anatomy. Iliac artery angiography should be considered in patients with severe vascular disease to rule out significant atherosclerosis of the recipient vessel. Similarly, iliac venography is recommended to rule out venous obstruction in patients with longstanding retroperitoneal fibrosis or radiation. The nephrectomy is commonly performed laparoscopically[42] and the remainder of the procedure is carried out in an open fashion according to the standard concepts of renal transplantation, typically with the aid of a transplant surgeon. If the proximal ureter is short a BBF with pyelovesicostomy can be performed. During nephrectomy, effort must be made to provide as great a length of vein and artery as possible to improve the ease of implantation.

Early postoperative complications include bleeding from the vascular anastomosis, renal artery or vein thrombosis, distal extremity embolization, or urinary extravasation. Renal artery or vein thrombosis may result from hypotension in the postoperative period and should be ruled out in cases of oliguria following autotransplantation of a solitary kidney. The diagnosis is made with duplex renal ultrasound, and, if confirmed, immediate salvage surgery should be considered. Urinary extravasation is the most common complication from autotransplantation though placement of a double-J stent at the time of surgery diminishes this risk. The most common late complications include renal artery stenosis, ureteral stricture, and ureterovesical reflux. Renal artery stenosis may be manifested by hypertension or impaired renal function. Diagnosis is made by renal scan and CT or traditional angiography. Ureteral stricture can be managed as discussed elsewhere in this chapter. Long term, approximately 10% of renal units will be lost following autotransplantation.[43,44]

URETEROENTERIC ANASTOMOTIC STRICTURE

Benign ureteroenteric anastomotic stricture occurs in 3–14% of patients and more commonly involves the left ureter.[45–47] The etiology is typically ischemia and may be related to over mobilization or skeletonization of the ureter. Angulation of the left ureter under the superior mesenteric artery may also contribute. Several studies have failed to demonstrate a significantly different rate of stricture between Bricker and Wallace anastomosis types,[46,48] though nonrefluxing anastomoses likely have a higher rate of obstruction.[49] The typical presentation can include flank pain, infection, decreased renal function, and hydronephrosis, and confirmation of obstruction is made with nuclear renography, or lack of ureteral reflux on loopography. Stricture may present within months of surgery but occurrence at up to 6 years has been described.[50] Endourologic attempts at stricture management are best approached antegrade with intestinal diversions, partly due to the technical challenges of a retrograde approach. Success rates of balloon dilation are estimated at 30% or less.[51,52] Endoscopic incision has better outcomes, approaching 50–80%, though success rates are poorer on the left side.[47] Particularly on the left, one must be cautious with full-thickness endoureterotomy as the pathway of the ureter may abut the sigmoid mesentery or the iliac vessels. Given these concerns, open or robotic[53] repair of left ureteral stricture repair can be considered as an initial approach. It is critical to be familiar with the anatomy of the urinary diversion to avoid damage to the vascular pedicle or contralateral ureter. The same tenets of ureteral surgery apply to this procedure, including a tension-free, watertight anastomosis with internal stenting and external drainage. If the viable ureteral

length is insufficient an additional segment of bowel may be required as an interposition. Success rates of up to 80% have been reported with open repair, citing strictures longer than 1 cm and left-sided strictures as risks for failed repair.[47]

TRANSPLANT ANASTOMOTIC STRICTURE

Ureteral obstruction occurs in 2–10% of renal transplant patients postoperatively, may present within the first few weeks, and typically presents within the first year. Obstruction in the early postoperative period is often transient and successfully managed with stenting alone, whereas obstruction occurring after 3 months typically requires surgical intervention to achieve resolution.[54] Similar early ureteral complication rates of 2.1% and 2.8% have been demonstrated with the extravesical Lich-Gregoir and the intravesical Politano-Leadbetter ureteral implant techniques.[25,55,56] Transplant ureters may at times be sewn to native ureters when ureteral length is inadequate. Initial management of transplant ureteral obstruction is to ensure adequate drainage of the renal unit with nephrostomy tube or indwelling ureteral stent. Endoscopic intervention with balloon dilation has success rates of approximately 50%, and rates are slightly higher with laser or electroincision of the stricture. If initial endoscopic intervention fails, the success rate of a repeat endoscopic procedure is closer to 25%.[57] Understanding the transplant anatomy and abiding by the tenets of ureteral reconstructive surgery should guide the surgeon toward successful reintervention. Complications are similar to those with autotransplant albeit the patient is immunosuppressed and is completely reliant on the transplanted kidney.

URETEROLYSIS

Ureterolysis consists of removing fibrous tissue off the length of the ureter that has resulted from retroperitoneal fibrosis. Such fibrosis occurs for various reasons, most commonly idiopathic, and causes scar tissue formation along the aorta and iliac arteries that eventually grows around the ureter resulting in medialization and obstruction. On imaging the ureter may not appear dilated due to encasement, but hydronephrosis is typically present and the obstruction is confirmed with diuretic renogram. The process may be unilateral or bilateral. Along with ureterolysis, mobilization of the abdominal and pelvic ureter away from the inflammatory process with lateralization or intraperitoneal transposition and preferably with an omental wrap is recommended to prevent recurrence or progression. Omental wrap also increases blood flow to the ureter. Ureterolysis may be done in an open or laparoscopic (robotic) fashion. Success rates approximating 83–92% are reported,[58–60] with laparoscopic ureterolysis providing similar outcomes and shorter convalescence compared to open surgery.[59] A ureteral stent should be placed preoperatively to aid in ureteral identification and remain for 2–4 weeks. With complete mobilization, the ureter is dependent on its proximal and distal blood supply, and thus is at risk for ischemic stricture, particularly if injury to the adventitia of the ureter is made during the often challenging dissection. A clean plane of dissection of the fibrous tissue from the ureter will decrease the recurrence of obstruction. Ureterotomy is a common complication (11%) that may be immediately identified and repaired.[61] Major complications such as injury to the iliac or great vessels can occur. Omental wrap of the ureter has been suggested to increase the rate of late intestinal obstruction in open ureterolysis,[62] though contemporary laparoscopic studies have not described this complication.[59,61] When dissection proves challenging, or a section of the ureter has been obliterated, ureterolysis may be combined with Boari flap, nephropexy, ileal ureter, or autotransplantation.

POSTOPERATIVE STENTING AND DRAINAGE

Generally, placement of an indwelling ureteral stent for all surgical procedures involving a ureteral anastomosis or extensive mobilization of the ureter is recommended. For ureteroneocystostomy and ureteropelvic junction repairs, it is helpful to place a longer stent than necessary to keep the stent coil away from the anastomosis while suturing. Stent migration can occur in a dilated ureter or with excessive manipulation of the repair and is typically confirmed by imaging when patients become symptomatic. Nephrostomy tube placement can be considered if migration occurs early in the postoperative period, to avoid risking injury to the ureteral anastomosis with retrograde stent manipulation. Indwelling stent duration for most ureteral surgery is 4–6 weeks. Suppressive antibiotics for indwelling ureteral stents are not routinely recommended, but one can consider oral antibiotic prophylaxis before stent removal to reduce the risk of bacteremia.

Nephrostomy tubes are often in place at the time of surgery. The decision to remove a nephrostomy tube at the time of surgery is surgeon preference, but it may be preferable to maximally drain the renal unit until the success of the repair can be determined. The nephrostomy tube may be removed after a "capping" trial without significant pain or leakage around the tube, or after nephrostogram to confirm antegrade drainage. Removal under radiologic guidance is recommended when an indwelling stent is in place, to ensure that the indwelling ureteral stent is not displaced into the nephrostomy tract, as this could result in urine leak and fistula formation.

External drains are a useful adjunct in ureteral reconstructive surgery procedures and serve to monitor and control potential urine leaks. Drains should be placed in a dependent area and not directly over the site of an anastomosis, as this may exacerbate a urinary leak. Leakage should be suspected with persistently high outputs and can be confirmed by checking fluid creatinine levels. If a leak is detected, maximal drainage should be continued, including bladder drainage. In the era of minimally invasive surgery drains are often removed prior to hospital discharge on postoperative day number 1 or 2, before leakage from ischemic necrosis would typically present. Without drainage, leakage may result in urinoma, with some patients remaining asymptomatic while others present with flank pain or abdominal pain, fever, or ileus. When suspected, CT of the abdomen and pelvis with delayed phase (urogram) is the study of choice. Delayed images may reveal the presence and location of the urine leak. Prolonged maximal drainage of the urinary system will provide opportunity for resolution. CT or ultrasound-guided

percutaneous drainage of any urinoma may be appropriate, and mandatory if infection is suspected. When a suction drain is present and in proximity to the anastomosis, suction can be stopped to encourage urine to drain via the natural or reconstructed pathway. Prolonged urinary leakage from the anastomosis may require the placement of a nephrostomy tube for proximal urinary diversion.

A Foley catheter is typically left in place after ureteral repair and is mandatory after BBF. For surgeries not involving a cystotomy, the Foley is typically removed on postoperative day 1. The external drain should be monitored for an increase in output after Foley removal. If the increased drain output is confirmed to be urine, prolonged bladder drainage is needed. Similarly, if patients develop symptomatic flank pain after Foley removal, continued drainage is appropriate. A cystogram can be done prior to Foley removal to ensure healing for surgeries involving a cystotomy, particularly in patients with a history of radiation, diabetes, or immunosuppression.

GENERAL COMPLICATIONS AND MANAGEMENT

Urine Leakage

Urinary extravasation that is persistent from the time of surgery is likely due to a technical error and usually heals with prolonged drainage. For significant or persistent leaks, a nephrostomy tube may need to be placed in addition to internal ureteral stenting. With this combination the fistula will heal without stricture development or renal compromise in 63–95% of cases.[63–66] In contrast, leakage that begins several days after surgery may be attributed to ischemic necrosis. Drainage remains the mainstay of management though there is an increased risk of ischemic stricture formation and a higher likelihood that repeat surgical repair will be needed.

Ureteral Stricture

For most reconstructive ureteral surgery, diuretic renal scan can be performed at 3 months postoperatively to confirm patency of the repair. Recurrent obstruction is a long-term risk, and thus renal ultrasound is recommended every 6 months in the first 1–2 years after repair. Postoperative ureteral stricture formation is confirmed when urography, renal scan, or Whitaker testing confirms obstruction.

Endourologic interventions should be considered when possible following ureteral reconstructive surgery. These may include antegrade or retrograde balloon dilation, hot- or cold-knife incision, laser incision, or incision with an Acucise catheter system (Applied Medical Resources Corp., Laguna Hills, CA). Endoscopic success rates have been discussed previously in this chapter. Generally, endoscopic interventions are less likely to be successful for anastomotic strictures than for strictures secondary to stone disease or iatrogenic injury that occur in an intact ureter because anastomotic strictures are most commonly ischemic in nature. Balloon dilation and endopyelotomy rely on full-thickness fracturing or cutting of the urothelium and healing by secondary intention via re-epithelialization. This process requires an adequate blood supply. Whereas strictures in the native ureter benefit from a dual blood supply from the caudal and cephalad portions of the ureter, a ureter implanted into the anti-mesenteric aspect of a bowel segment, a recipient ureter, or bladder flap will have a tentative blood supply from the recipient structure, making healing by re-epithelialization after endoscopic intervention less likely.

References

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Chapter 43 Questions

1. A 62-year-old woman develops a 3.0-cm benign ureteral stricture at the left ureteroileal anastomosis 7 months after a radical cystectomy and neobladder. The left renal function is 30%. The next step is:
   a. Endoscopic laser incision
   b. Endoscopic balloon dilation
   c. Metallic stent placement
   d. Open surgical repair
   e. Re-evaluation in 3 months

2. A 21-year-old man with a history of multiple ureteroscopic interventions for recurrent nephrolithiasis has left flank pain. He is afebrile, and serum creatinine (Cr) is 1.1 mg/dL. CT urogram is negative for stones but demonstrates left hydronephrosis and a 7-cm ureteral stricture from the left UPJ to the midureter. Lasix renal scan shows left renal function of 40% and T ½ of 40 minutes after diuretic administration. The next step is:
   a. Ileal ureter
   b. Transureteroureterostomy
   c. Nephrectomy
   d. Endopyelotomy
   e. Bucal mucosa graft

3. A 38-year-old woman underwent Boari bladder flap (BBF) with nephropexy for a chronically obstructed left kidney secondary to a 6-cm midureteral stricture that developed after left ovarian cyst excision 1 year previously. She subsequently developed nonresolving urinary leakage from the proximal portion of the BBF and she is currently managed with a left nephrostomy tube. Her serum Cr is 1.6 mg/dL, and the left kidney provides 55% function on functional renal scan. Her medical history is notable for Crohn's disease. The best option is:
   a. Ileal ureter
   b. Nephrectomy
   c. Renal autotransplantation
   d. Primary repair of the Boari flap
   e. Conversion to a double 'j' ureteral stent

4. A 54-year-old woman undergoes robotic Boari bladder flap with right ureteral reimplant for ureteral injury involving her entire right pelvic ureter. An indwelling ureteral stent was placed. Foley catheter is removed on postoperative day 1 and she subsequently develops urinary urgency and severe right flank pain. External drain output is low and consistent with serum Cr. The first step is:
   a. Nephrostomy tube
   b. Antibiotics
   c. Scheduled anticholinergic
   d. Replace Foley catheter
   e. Surgical laparotomy

5. A 34-year-old woman has left hydronephrosis on renal ultrasound 6 months after a robotic extravesical left ureteral reimplant. Serum Cr is 0.8 mg/dL. She has no flank pain and completely empties her bladder with voiding. The next step is:
   a. Cystoscopy with retrograde pyelography
   b. Diuretic nuclear renal scan
   c. Observation
   d. Voiding cystourethrogram (VCUG)
   e. Percuteanous nephrostomy tube placement

6. A 43-year-old woman undergoes a vesicopsoas hitch with right ureteral reimplant for a distal ureteral injury noted at the time of abdominal hysterectomy. Two 2-0 absorbable sutures are used to secure the detrusor muscle to the psoas major muscle. Postoperatively she notes right leg weakness and difficulty climbing stairs that is persistent at her 1-week follow-up. The next step is:
   a. MRI of the lumbar spine
   b. Antibiotics
   c. Referral to physical therapy
   d. Operative removal of the psoas hitch sutures
   e. Posterior tibial nerve stimulation

7. A 48-year-old woman undergoes abdominal radical hysterectomy. Routine cystoscopy by the gynecology service before conclusion of the case fails to identify left ureteral efflux, despite methylene blue administration. Exploration reveals ureteral entrapment from suture ligation of the left uterine artery. The best management is:
   a. Excision of distal ureter with reimplantation
   b. Excision of entrapped ureter with ureteroureterostomy
   c. Removal of suture
   d. Removal of suture with placement of indwelling ureteral stent
   e. Ureteral balloon dilation of the area of narrowing

8. A 36-year-old woman undergoes robotic-assisted hysterectomy. The surgeon identifies the distal left ureter is partially entrapped in a vessel sealing device while applying bipolar energy and stops applying the energy. Grossly the ureter appears to have sustained a 25% partial transection. The best management is:
   a. Robotic ureteral reimplant
   b. Primary closure of the ureteral laceration without narrowing the diameter
   c. Place a ureteral stent
   d. Observation with contrast imaging in 2 weeks
   e. Transureteroureterostomy

9. A 36-year-old female underwent laparoscopic hysterectomy for uterine fibroids. She developed left flank pain 3 days later and a nephrostomy tube was placed for confirmed distal ureteral injury. This was removed after 4 weeks. She now presents 1 month later with nausea, vomiting, and left flank pain. She is afebrile. CT urogram suggests a small distal ureteral leak and resultant 2-cm urinoma. What is the next step?
   a. Cystoscopy, retrograde pyelogram, and retrograde stent placement with Foley catheter
   b. Nephrostomy tube
   c. Placement of a nonsuction external drain

d. Ureteral reimplant
e. Antibiotics and re-evaluation in 2 weeks

10. Ureteral stents used during the management of idiopathic retroperitoneal fibrosis:
    a. Are removed immediately after ureterolysis
    b. Do not help identify the ureters during ureterolysis
    c. Are placed without difficulty most of the time
    d. All of the above
    e. None of the above

Case Study 1

A 78-year-old man with multiple comorbidities develops a 3.0-cm ureteral stricture at the left ureteroileal anastomosis 5 months after a radical cystectomy and ileal conduit were performed for muscle invasive bladder cancer. Bricker anastomoses were done. Ureteral margins were negative for carcinoma. Cr is 2.0 mg/dL and the left renal function is 45% with T ½ > 40 minutes on diuretic renogram.

1. What is the most likely etiology of his stricture?
    a. Ureteral cancer
    b. Ischemia from anastomotic tension or devascularization
    c. Use of a Bricker anastomosis instead of a Wallace style
    d. Poor renal function
    e. Suture ligation

2. He has had two episodes of pyelonephritis and urosepsis in the past 2 months with ureteral stent in place, and thus a nephrostomy tube was placed. Loopogram and antegrade nephrostogram images (Case Fig. 43.1) are seen below. The best option is:
    a. Metallic stent placement
    b. Endoscopic balloon dilation
    c. Transureteroureterostomy
    d. Robotic ureteral reimplant into ileal conduit
    e. Total conduit revision

Case Study 2

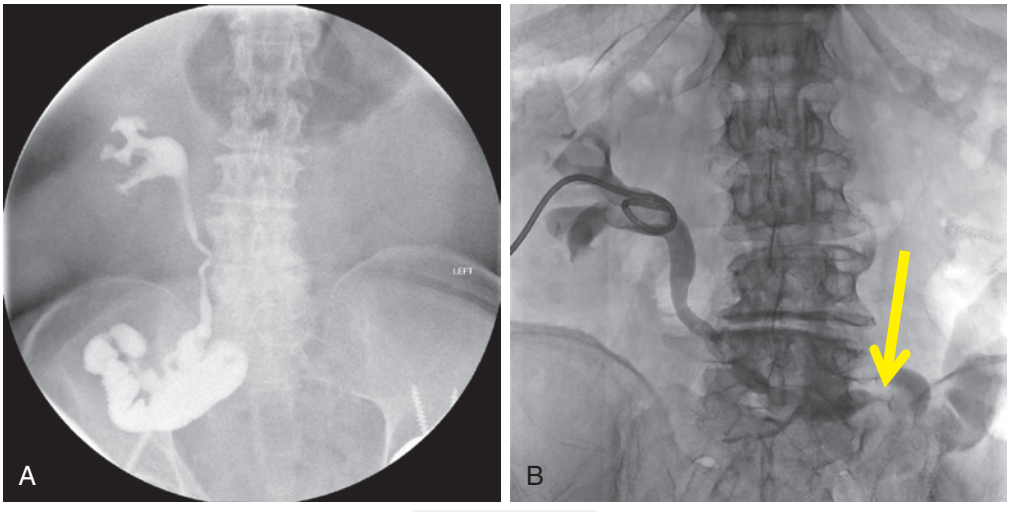
A 35-year-old female underwent robotic hysterectomy for uterine fibroids. She presents 3 weeks later with abdominal pain, nausea, and vomiting. CT scan suggests a 2.0-cm fluid collection in the pelvis.

1. What is the next step?
    a. Delayed contrast imaging
    b. Interventional radiology guided drain placement
    c. Nephrostomy tube
    d. Consult gynecology
    e. Pre-emptive ureteral stent placement

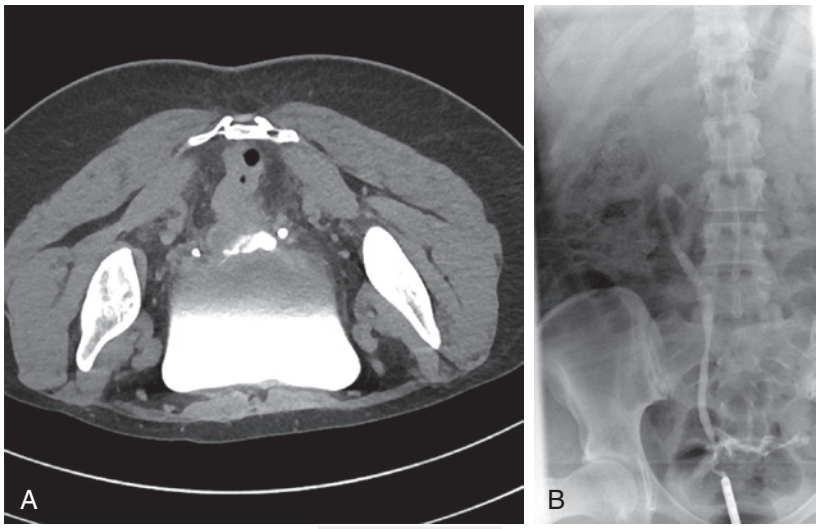
2. Delayed contrast imaging is obtained and demonstrates urine leak (Case Fig. 43.2) from the distal right ureter. Retrograde stent placement is not successful so a nephrostomy tube is placed and symptoms resolve. She is planned for operative reconstruction 1 month later. What is the best procedure?
    a. Boari bladder flap with ureteral reimplant
    b. Primary ureteral repair (ureteroureterostomy)
    c. Psoas hitch with ureteral reimplant
    d. Antegrade stent placement and prolonged bladder drainage
    e. None of the above

A robotic extravesical ureteral reimplant with psoas hitch is performed. On postoperative day number 1, the patient notes numbness over the right anterior thigh and the right aspect of her mons pubis.

3. What is the probably etiology of her symptoms?
    a. Entrapment of the femoral nerve by psoas hitch suture
    b. Entrapment of the genitofemoral nerve by psoas hitch suture
    c. Lithotomy position
    d. Bladder spasms
    e. Osteomyelitis



Case Figure 43.1



Case Figure 43.2

Answers

1. **d.** Once disease from cancer recurrence is ruled-out, the most effective means to address a longer stricture (>2.0 cm) is with open (or robotic) repair. This early ureteroenteric stricture (less than 1 year postoperatively) is likely due to ischemia from devascularization and/or angulation of the left ureter under the inferior mesenteric artery. Endoscopic treatment will not likely be successful for a long ischemic stricture. Chronic ureteral stenting is not preferred in younger patients.
2. **a.** Ileal ureter should be considered for long (>4.0 cm) proximal ureteral defects in patients with serum Cr <2.0 mg/dL. It also facilitates stone passage and is thus a preferred option for a recurrent stone former. Endoscopic approaches may be effective for shorter strictures (1–2 cm or less). Transureteroureterostomy is contraindicated in those with nephrolithiasis and would not be possible due to the proximal nature of the stricture. Nephrectomy should be a last resort and classically is reserved for kidneys with <20% function on diuretic renal scan. Other options for this patient would include autotransplantation or buccal mucosal graft.
3. **c.** Nonresolving leakage from the BBF is most likely due to ischemia of the flap. A tension-free primary repair is unlikely to be feasible. Ileal ureter is contraindicated in patients with inflammatory bowel disease. Nephrectomy is reserved for kidneys providing <15% renal function though this is not an unreasonable approach in patients that have already undergone and failed reconstructive surgery. An attempt at renal autotransplantation is preferred in this patient with depressed renal function.
4. **c.** The patient is experiencing bladder spasms, which are common after a significant incision of the detrusor muscle as with BBF. The indwelling ureteral stent permits reflux to the kidney resulting in flank pain. Foley catheter placement may improve her symptoms, but in the absence of urinary leak should not be replaced unless anticholinergics prove unsuccessful.
5. **b.** Hydronephrosis after ureteral surgery may be related to obstruction, reflux, or residual from chronic dilation. VCUG can evaluate for ureteral reflux, though studies have demonstrated that reflux is not detrimental to long-term renal function. Diuretic renal scan should be used to assess for functional obstruction in patients with normal renal function when postoperative imaging is equivocal. We routinely perform a renal scan on all patients postoperatively to monitor for treatment success. Cystoscopy is more invasive, and observation risks permanent damage to the kidney if obstruction is present.
6. **c.** The patient's symptoms may be related to femoral nerve edema from retractor compression of the psoas muscle or could be secondary to nerve entrapment from the hitch sutures. Early mobilization and referral to physical therapy are beneficial to recovery for either mechanism. If entrapment is the issue, symptoms should be expected to eventually resolve since absorbable suture was used. If permanent suture was used a return to the operating room would be appropriate.
7. **d.** Ureteral entrapment that is immediately identified can be resolved with suture removal. If the ligation had a delayed recognition, the areas of the ureter may become fibrotic or ischemic putting the patient at risk for stricture, and making excision more appropriate. Ureteral stenting is preferred, as suture ligation will likely result in edema postoperatively that could result in temporary obstructive symptoms.
8. **a.** Primary closure can be appropriate for partial lacerations of the ureter, though in this case the thermal energy from the vessel sealing instrument could result in further injury to the tissue with delayed necrosis. Thus, excision of the injured area with a minimum of a 1-cm margin is the best option. A ureteral stent can permit healing of a partial laceration such as from endoscopic injury, but success is less likely with thermal injury for the above reasons and the current operative setup is favorable for an immediate repair.
9. **a.** Cystoscopy with retrograde pyelogram will help define the level and significance of the ureteral injury and potentially allow placement of a ureteral stent. Stenting the ureteral injury may allow primary healing.

If retrograde stent placement is not successful, nephrostomy tube placement is appropriate and antegrade stent placement could be considered. The urinoma is small and may resorb if the ureteral defect is bridged. Drainage of the urinoma should be done if physical symptoms persist after renal drainage or if there is any evidence for infection.

10. **c.** Placement of ureteral stents in retroperitoneal fibrosis (RPF) is typically not challenging, a contrast to obstructive processes caused by malignancy. Stents are placed preoperatively to aid in ureteral identification and mobilization and should remain in place for a minimum of 2–4 weeks after ureterolysis.

CASE STUDY 1

1. **b.** This early ureteroenteric stricture (less than 1 year postoperatively) is likely due to ischemia from devascularization and/or angulation of the left ureter under the inferior mesenteric artery. Ureteral cancer recurrence this early is unlikely with negative ureteral margins, but should be ruled out. Several studies have failed to show a statistically significant difference in the rate of ureteral stricture when comparing Bricker and Wallace style anastomoses.
2. **d.** Once disease from cancer recurrence is ruled out, the most effective means to address a longer stricture (>2.0 cm) is with open (or robotic) repair. Endoscopic treatment will not likely be successful for a long ischemic stricture. There are no data to suggest that metallic stents will reduce the risk of infection. Transureteroureterostomy puts the uninvolved renal unit at risk. The best option is to reimplant the ureter. Robotic reimplant may provide shorter convalescence and expedite recovery for this gentleman.

CASE STUDY 2

1. **a.** The fluid collection could be postoperative or could be a urine leak. The next step is to confirm the presence of urine leak and the level of ureteral injury. This can be done with cystoscopy and retrogrades, or nephrostomy with antegrade imaging, but a delayed phase of the CT is less invasive. Drain placement with fluid sampling would confirm the urine leak but provide no information about the location of the leak and is premature at this point for a small collection.
2. **c.** The delayed contrast imaging demonstrates that the distal ureteral injury is very close to the bladder. Retrograde imaging demonstrates a leak, but contrast reaches the proximal ureter suggesting there is not a complete transection. After nearly 2 months, this ureteral injury is unlikely to heal over a stent. Ureteroureterostomy is for proximal and midureteral strictures. Boari bladder flap is unnecessary for such a distal ureteral stricture. The ureter could likely be directly reimplanted into the bladder with such a distal injury, though a psoas hitch will reduce anastomotic tension.
3. **b.** The femoral nerve runs within the psoas major muscle, and the genitofemoral nerve runs anterior to this muscle. Either has the potential to be entrapped with psoas hitch. Femoral nerve injury would result in reduced hip flexion and knee extension that presents as gait difficultly, particularly with ascent of stairs. The most common nerve injury in the lithotomy position is to the peroneal nerve, resulting in temporary drop foot. The symptoms described in this case are consistent with entrapment of the genitofemoral nerve and will likely eventually resolve if absorbable suture was used.

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44 Complications of Renal Transplantation

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CHAPTER OUTLINE

Basic Operative Procedure
Surgical Challenges
Multiple Vessels
Perioperative Anticoagulation
Severe Recipient Peripheral Vascular Disease
Poor Graft Perfusion
Bleeding
Immunosuppression Toxicity
Cardiovascular Disease
Urologic Complications
Urinary Extravasation
Obstruction
Reflux
Hematuria
Vascular Complications
Hematomas
Renal Artery Stenosis
Renal Artery Thrombosis
Renal Vein Thrombosis
Deep Vein Thrombosis and Pulmonary Embolism
Lymphocele
Arteriovenous Fistula
Graft Rejection
Chapter 44 Questions and Answers

KEY POINTS

1. As the demand for kidney transplantation continues to rise, urologists will increasingly be called on to participate in donor and recipient care.
2. The allograft ureter receives blood supply solely from the renal artery; therefore, preservation of all the arterial branches (especially lower pole arteries) is essential to ensure viability of the ureter.
3. A stented ureteroneocystostomy has four times fewer urologic complications than a non-stented ureteroneocystostomy.
4. If a urine leak is caused by an ischemic sloughed ureter, endoscopic management merely delays definitive treatment. Therefore early surgical exploration and repair is usually the best solution.
5. Recipients who develop recurrent pyelonephritis after transplantation with confirmed reflux on imaging studies initially should be treated with long-term antibiotic prophylaxis. If this approach is not effective, then an endoscopic or open procedure may be indicated.

Minor complications can quickly become life threatening for immunosuppressed patients after renal transplantation. More than 100,000 patients are currently on the national kidney transplantation waiting list, and approximately 450,000 patients are on dialysis.[1] Thus, the demand for kidney transplantation continues to rise. In 2013, approximately 11,878 deceased donor and 5721 living donor kidney transplants were performed in the United States. Community urologists and general surgeons will increasingly be called on to participate in donor and recipient care. Early recognition of renal transplant complications can prevent serious morbidity and mortality. This chapter focuses on how to prevent and treat the complications of renal transplantation.

Basic Operative Procedure

To avoid renal transplant complications, patients should be carefully screened for cardiac disease and severe peripheral vascular disease. However, because the most common causes of end-stage renal disease are diabetes and hypertension, many patients already have these problems. Patients with progressive renal insufficiency should be referred to a nephrologist and kidney transplant program well before they need renal replacement therapy.

A retroperitoneal lower abdominal incision is used to expose the iliac vessels. The donor kidney is prepared by removal of the perinephric adipose tissue and ligation of small branches off the renal vessels. The donor kidney is

kept ice cold until the time of reperfusion by wrapping a gauze pad with crushed ice saline around it. The renal vein or vena caval extension graft is anastomosed to the external iliac vein, and the renal artery is anastomosed to the iliac artery. If possible, a patch of the donor aorta is used to facilitate the arterial anastomosis. Intravenous furosemide and mannitol are administered to reduce ischemia reperfusion injury. The ice pad and the vascular clamps are removed. Once hemostasis is achieved, the graft is carefully positioned to avoid kinking of the vessels. The ureter is passed beneath the spermatic cord and is anastomosed to the bladder mucosa with a stented extravesical approach. A submucosal tunnel is created to prevent reflux.

Surgical Challenges

MULTIPLE VESSELS

In deceased donor transplants, multiple arteries can be kept on a Carrel aortic patch; occasionally when the arteries are far apart, a section of the Carrel patch can be excised and re-approximated. However, when a living donor kidney has multiple arteries, these need to be anastomosed individually to the recipient or to one another so that one accommodating donor artery can be anastomosed to the recipient. If two arteries are approximately the same size, we prefer to use the "pair of pants" technique before anastomosing to the recipient vessel. When the vessels are of different caliber or length, an end-to-side technique may be the most appropriate option. Other options for multiple arteries include: (1) using the recipient's inferior epigastric artery in an end-to-end fashion with a donor artery and (2) harvesting the recipient's internal iliac artery and using it to accommodate multiple donor arteries. If the surgeon has exhausted these options, most transplant centers have a bank of vessels from deceased donors that can aid in the vascular reconstruction. In any event, a lower pole branch should always be preserved to avoid ureteral necrosis.

If multiple donor renal veins are available, the largest should be used and the others can be ligated because of internal venous collateralization. If two veins are approximately the same size, they can be sewn together with the "pair of pants" technique or individually anastomosed to the recipient's iliac vein. For right deceased donor kidneys, it is helpful to include the vena cava to extend the venous length.

PERIOPERATIVE ANTICOAGULATION

Anticoagulation is required for patients with mechanical cardiac valves, atrial fibrillation, and other diseases that increase the risk of venous thrombosis and pulmonary embolus. For patients admitted for deceased donor renal transplantation who are receiving warfarin, the international normalized ratio (INR) should be corrected to <2.5 at the time of the operation. Patients with a history of a coagulopathy or an increased risk of anastomotic thrombosis (peripheral vascular disease or multiple small vessels requiring vascular reconstruction) are anticoagulated with heparin. To limit the risk of postoperative bleeding a small bolus of 500 U followed by a continuous infusion of 100 U per hour has been successful in preventing graft thrombosis.

SEVERE RECIPIENT PERIPHERAL VASCULAR DISEASE

Even after computed tomography (CT) and magnetic resonance imaging (MRI) studies, as well as a thorough history and physical examination, a transplant surgeon may discover severe peripheral vascular disease affecting the pelvic vasculature at the time of the surgical procedure. Most calcified vessels have a soft spot along the external or common iliac artery that can accommodate the donor artery. Noncrushing Fogarty shodden vascular clamps can occlude areas with plaque with less risk of intimal injury. In rare cases the artery can be occluded internally with two Fogarty embolectomy catheters, and the balloons are deflated and removed when the assistant throws and ties down the last suture.

POOR GRAFT PERFUSION

On release of the vascular clamps the renal parenchyma should be pink and have appropriate turgor. Arterial signals should be detectable by Doppler probe in the hilar branches of the renal artery and major sections of the parenchyma. With deceased donor allografts, perfusion is frequently patchy but this resolves in approximately 10 minutes. The pulse in the renal artery should be palpably similar to that of the external iliac artery. The allograft must be positioned to avoid kinking of the vessels. If the hilum is positioned medially, the risk of vascular injury during percutaneous biopsy is reduced. Planning the final renal position and determining the best location before vascular anastomosis may reduce difficulty with graft positioning. Rarely, the graft may need to be placed low in the pelvis or intraperitoneally. This positioning makes renal allograft imaging and biopsy significantly more complicated, and revision of the vascular anastomosis should be considered. Arterial spasm can be relieved by topical or intraadventitial injection of papaverine or verapamil; however, this must be done with caution because of the risk of hypotension and heart block.

BLEEDING

Loss of <250 mL of blood is usually possible by careful hemostasis during exposure of the iliac vessels, ligation of small branches off the allograft vessels, and meticulous placement of the anastomotic sutures. Blood loss can be diminished by flushing the donor vessels with heparinized saline solution, following the preparation of the allograft and ligating the sites of extravasation. If blood loss is significant at the time of reperfusion, the vascular clamps should be reapplied and the graft carefully inspected.

Anastomotic bleeding can usually be controlled with fine suture ligatures. If the vessels have torn, it may be necessary to take down the vascular anastomoses and reconstruct the vessels on the back table. For this reason, the nursing staff should be instructed to leave the back table set up until the operation has been completed. In addition, do not infuse Collin's or UW (University of Wisconsin) solution into the transplant renal artery when the allograft is in situ and the venous anastomosis is complete. Otherwise the patient may develop heart block and cardiac arrest because of the high potassium content of these solutions. Oozing

from the anastomosis usually stops with gentle pressure and the application of cellulose gauze.

IMMUNOSUPPRESSION TOXICITY

The immunosuppressive medications used in renal transplantation may exacerbate or induce complications such as malignant disease, infections, diabetes mellitus, hematologic disorders, neurotoxicity, and metabolic disorders. Surgeons involved in the care of renal transplant patients must be aware of these complicating factors because they may have an impact on the optimal surgical management. Unlike heart or liver transplantation, dialysis provides an alternative renal replacement therapy. If severe complications occur, the recipient's life may need to be saved by discontinuation of immunosuppression.

CARDIOVASCULAR DISEASE

Patients with end-stage renal disease have a substantial risk for cardiovascular disease. Diabetes is the most common disease leading to renal transplantation, and almost all patients with renal failure develop hypertension. Additional cardiovascular risk factors associated with end-stage renal disease include increased extracellular fluid volume, anemia, high plasma levels of homocysteine, and thrombogenic factors. Additionally, uremia may accelerate atherogenesis and proteinuria is associated with hyperlipidemia. Patients who are undergoing dialysis and who are taking calcium salts as phosphate binding agents may develop vascular calcifications, which can complicate the technical aspects of the transplant operation.[2] Secondary hyperparathyroidism and a calcium × phosphate product of over 70 are risk factors for calciphylaxsis. Hyperphosphatemia is often associated with scleral hyperemia, pruritus, and peripheral vascular disease due to dystrophic crystallization. Cardiovascular risk factors are exacerbated by immunosuppression that can cause glucose intolerance (corticosteroids and calcineurin inhibitors) and hyperlipidemia (sirolimus and calcineurin inhibitors). Cardiovascular disease is the leading cause of allograft loss and death after transplantation. Prevention and careful preoperative evaluation rather than treatment are the best ways to avoid cardiovascular complications.

Urologic Complications

URINARY EXTRAVASATION

Ischemia of the distal ureter, the most common cause of urinary extravasation, results in leakage at the ureterovesical anastomosis. The allograft ureter depends on blood supply solely from the renal artery; therefore, preservation of all the arterial branches (especially lower pole arteries) is essential to ensure viability of the ureter. Careful procurement of kidneys and the practice of leaving the shortest length of ureter that allows for a tension-free ureterovesical anastomosis also help to ensure an adequate blood supply to the distal ureter. A stented Lich-Gregoir ureteroneocystostomy has the lowest incidence of urinary extravasation and other urologic complications.[3–5] It is helpful to distend the bladder with antibiotic solution before ureteral implantation. The bladder mucosa should be mobilized sufficiently to allow the ureter to swell without constriction in the antireflux tunnel. The anastomosis can also be tested for leakage by gently refilling the bladder. This brief procedure also ensures that the ureter has been anastomosed to the bladder because anastomosis to an ovarian cyst, the vagina, and thickened folds of peritoneum have been reported.[6]



Figure 44.1 Cystogram demonstrating a bladder leak. Note the small-capacity bladder in a patient who was anuric for approximately 10 years.

In general, most cases of urinary extravasation occur soon after transplantation and manifest with allograft tenderness and decreased urinary output. Increasing wound drainage is also a frequent finding. The diagnosis can sometimes be made by ultrasound examination but is confirmed by creatinine analysis of the draining fluid, by nuclear medicine scan, or by cystogram (Fig. 44.1). Occasionally, upper urinary tract extravasation from a calyx, the renal pelvis, or ureteral injury is best diagnosed by a contrast imaging study or an antegrade nephrostogram. Small leaks in the bladder may be treated with Foley catheter drainage. Antegrade stent and nephrostomy tube placement may also provide sufficient drainage to allow closure of a very small leak. If the leak is caused by an ischemic sloughed ureter, endoscopic management merely delays definitive treatment. Therefore, early surgical exploration and repair are usually the best solutions. The type of repair depends on the level of the leak and the vasculature of the tissues. A bladder leak can be closed primarily, with a Foley catheter left in place for ≥1 week and confirmation of closure by repeat cystogram. Ureteral leaks are best treated by resection of the distal ischemic segment and reimplantation into the bladder over a stent. If the length of ureter is inadequate, then cystopyelostomy (sometimes requiring a psoas hitch or Boari flap) and ureteroureterostomy to the recipient's native ureter are both viable options.

OBSTRUCTION

Common causes of allograft ureteral obstruction include Foley catheter blockage, blood clots, ureteral edema, ischemic ureteral fibrosis (stricture), kinked ureter or extrinsic compression from a lymphocele, urinoma, and hematoma.

Other less common causes of obstruction include stones, prostatic hyperplasia, neurogenic bladder, abscess, rejection (which includes the ureter), and urethral strictures. Obstruction may be painless because of the absence of innervation to the renal allograft. However, obstruction should be suspected in any patient with an unexplained decrease in urine output, enlargement or tenderness of the allograft, and a rising serum creatinine level. Increasing hydronephrosis on ultrasonography is suggestive of obstruction, but this sign is not always present (Fig. 44.2). Low-grade dilation of the collecting system in the early postoperative ultrasound scan may occur with vigorous diuresis or edema and resolves. A mercaptotriglycylglycine (MAG3) diuretic renal scan is useful to determine whether physiologic obstruction is present.

Rapid relief of obstruction can be achieved by placement of a percutaneous nephrostomy tube and antegrade stenting. If obstruction is present, the serum creatinine concentration should decrease following this procedure. Some minor obstructive processes may resolve over time with proximal diversion and stenting. Stones, blood clots, and strictures <1 cm can often be treated endoscopically.[7] More complex obstructions require open repair. Strictures >2 cm require excision and reimplantation of the remaining healthy ureter into the bladder or native ureter as described in the previous discussion of urinary extravasation (Fig. 44.3). Extrinsic ureteral obstruction from a lymphocele, hematoma, or urinoma can generally be successfully treated with external drainage.

Often obstruction can be avoided. Elderly men who have been anuric while undergoing dialysis may have unrecognized prostatic hypertrophy. Following transplantation, this population of patients may benefit from an alpha-blocker or a 5α-reductase inhibitor. If one clinically suspects a voiding abnormality, a post-void residual determination should be obtained to detect urinary retention. Transurethral resection of the prostate (TURP) should not be performed unless the recipient has adequate urine output, because a "dry TURP" can lead to bladder neck contracture or urethral strictures. The complications of endoscopic surgery can be reduced by waiting until the renal allograft has recovered and the patient is receiving a reduced dose of immunosuppression. Self-intermittent catheterization has the least risk for urinary tract infection until the cause of voiding dysfunction has been evaluated and treated. Long-term indwelling catheters should be avoided if possible.

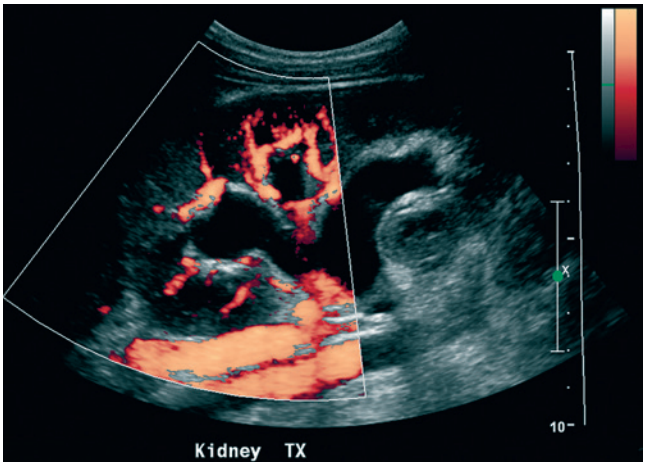


Figure 44.2 Hydronephrosis on renal ultrasound. This image suggests obstruction of the renal allograft. Note the decreased flow to the cortex of the kidney, and the prominent iliac vessels on the power Doppler image.

REFLUX

Although it is not a complication in and of itself, avoiding reflux into the allograft is theoretically desirable to reduce the pressure effects and pyelonephritis that may lead to impaired graft function. Some investigators have supported this theoretical advantage.[8–10] However, this finding has not been confirmed by others.[11–16] Urinary reflux into the renal allograft is usually identified during evaluation of recurrent urinary tract infections and is usually painless. A detrusor tunnel that is five times the diameter of the ureter should be attempted when possible. Most renal transplant surgeons prefer to use the stented Lich-Gregoir extravesical technique.[17,18] When ureteral length is compromised or when the patient has poor bladder capacity, a refluxing anastomosis is an acceptable option. Recipients who develop recurrent pyelonephritis after transplantation with confirmed reflux on imaging studies

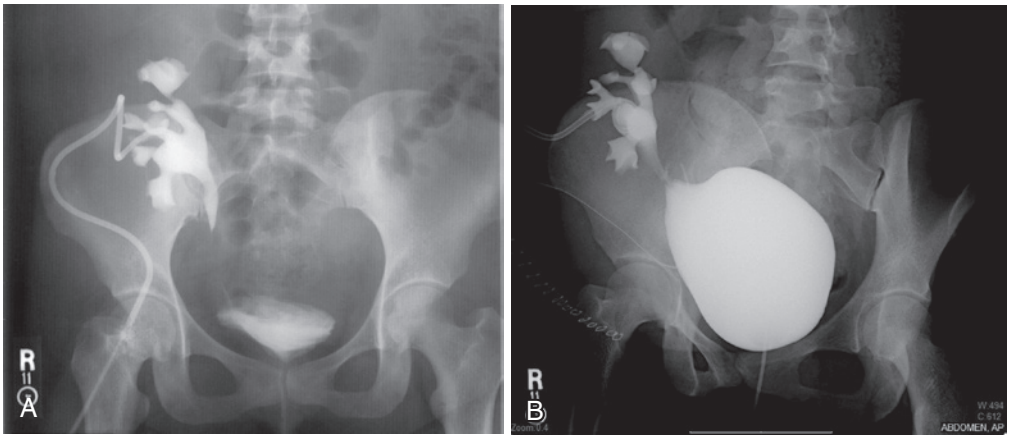


Figure 44.3 A, Anterograde nephrostogram of a distal ureteral stricture that manifested with a rising creatinine 6 months after allograft rejection and 5 years after renal transplant. B, Anterograde nephrostogram after urinary reconstruction with pyelovesicostomy.

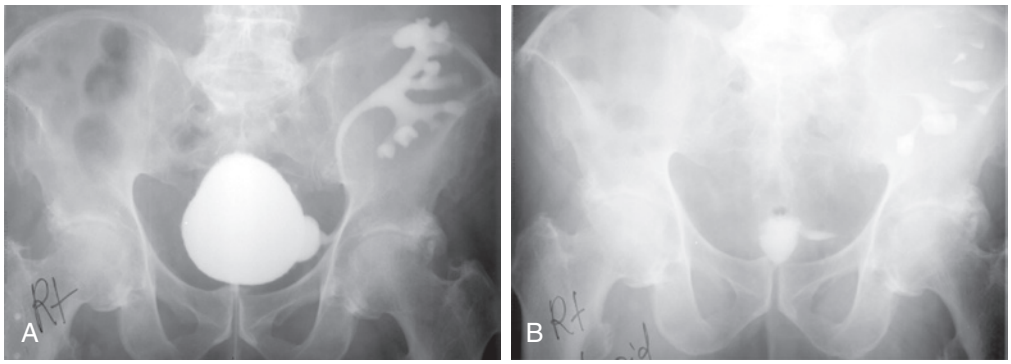


Figure 44.4 Voiding cystourethrogram. A, Reflux into the transplanted collecting system, with a diverticulum at the site of the ureteral anastomosis. B, Note some retained contrast after voiding.

(Fig. 44.4) should initially be treated with long-term antibiotic prophylaxis. If this approach is not effective, then an endoscopic or open reconstructive procedure may be indicated. Videourodynamics can be helpful to identify underlying bladder dysfunction and to determine the optimal corrective treatment.

HEMATURIA

In general, most renal transplant recipients develop some form of hematuria in the early postoperative period. Mild hematuria tends to resolve spontaneously over a couple of days. Moderate hematuria may develop into clots that can block the Foley catheter and occasionally require gentle manual irrigation or continuous bladder irrigation to resolve. If continuous bladder irrigation is not enough to clear the hematuria, then cystoscopy with fulguration is required.

The source of the bleeding is usually the ureteric stump. Vessels of the ureteric stump should be ligated with absorbable suture before creation of the ureteroneocystostomy. Urokinase with its natural anticoagulation properties may be responsible for some persistent hematuria. Hematuria beyond 6 months following transplant should have a complete evaluation.

Vascular Complications

HEMATOMAS

Perioperative bleeding is usually caused by small vessels in the renal hilum that may not have been identified intraoperatively because of vasospasm. Close observation of vital signs and serial hematocrit determinations are necessary in the early postoperative period to detect bleeding. Most small perirenal hematomas are asymptomatic, although larger hematomas can produce significant flank pain, lower extremity edema, and venous or ureteral obstruction. Hematomas in the retroperitoneum often tamponade and can be treated conservatively; however, expanding hematomas and more than four units of blood usually require exploration.

Massive bleeding may occur with graft rupture or anastomotic leaks. Graft rupture may result from swelling from ischemia reperfusion injury or severe rejection.[19] An intraoperative biopsy specimen of the ruptured allograft should be obtained. If the renal parenchyma appears viable, the graft should be wrapped with polyglactin mesh; if hemostasis can be achieved, allograft nephrectomy may not be necessary.[20] Late anastomotic bleeding is rare unless the anastomosis is infected. In this case, allograft nephrectomy is almost always required. If necessary, the iliac artery may be ligated without loss of limb, and the resultant claudication may be relieved by a surgical bypass procedure.[21] During surgical exploration of hematomas, one should resist the temptation to remove blood clots that have dissected into the retroperitoneal fat, unless active bleeding is noted in the area, because it becomes increasingly difficult to achieve hemostasis in this region. Ultrasound examination reliably detects perinephric fluid collections, but CT provides a much better assessment of the extent of blood dissection into adjacent tissues (Fig. 44.5).

If one elects to manage the bleeding conservatively, then aspirin and anticoagulant medications should be discontinued if possible. Blood transfusions are administered to maintain a hematocrit of ≥20%. Uremia inhibits platelet function, and most patients undergoing dialysis have abnormal bleeding times.[22] The intravenous administration of 0.3 μg/kg of 1-desamino-8-D-arginine vasopressin (DDAVP) causes the release of factor VIII from endothelial storage sites and may promote coagulation, although the effect is largely absent after 8 hours and DDAVP may induce tachyphylaxis. Daily intravenous conjugated estrogen (Premarin) infusion of 0.6 mg/kg for 5 days also reduces the bleeding time in uremic patients.[23] Vitamin K deficiency is fairly common in patients with renal failure and a poor nutritional state, and other coagulation parameters should be evaluated and corrected.

RENAL ARTERY STENOSIS

One of the most common vascular complications is transplant renal artery stenosis (TRAS), with a reported incidence of 1.6–12%.[24–27] Most cases of TRAS occur within 3 years after transplantation. The presenting signs suggestive of TRAS include poorly controlled renin-mediated hypertension, increasing peripheral edema, decreased allograft function with or without the use of angiotensin-converting enzyme inhibitors, and the presence of a bruit over the allograft. Renal artery stenosis is suspected on ultrasonography when the peak systolic velocity is >200 cm per second

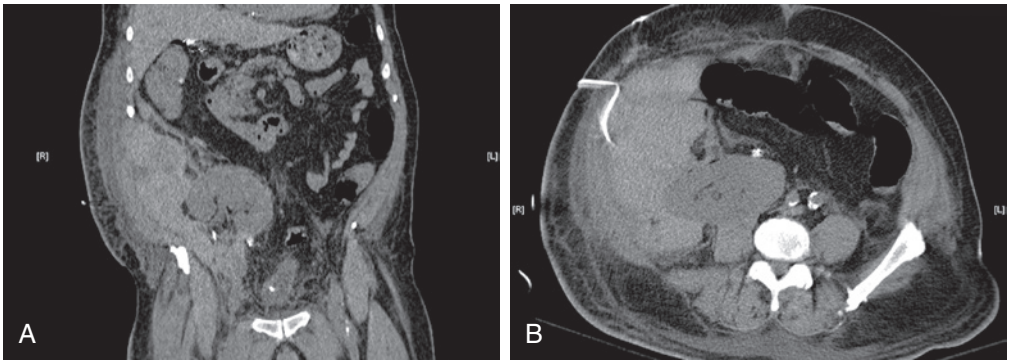


Figure 44.5 A, Coronal noncontrast CT scan of a large hematoma lateral to the renal allograft. B, Transverse noncontrast CT scan demonstrating that even a well-positioned drain does little to prevent hematoma formation.

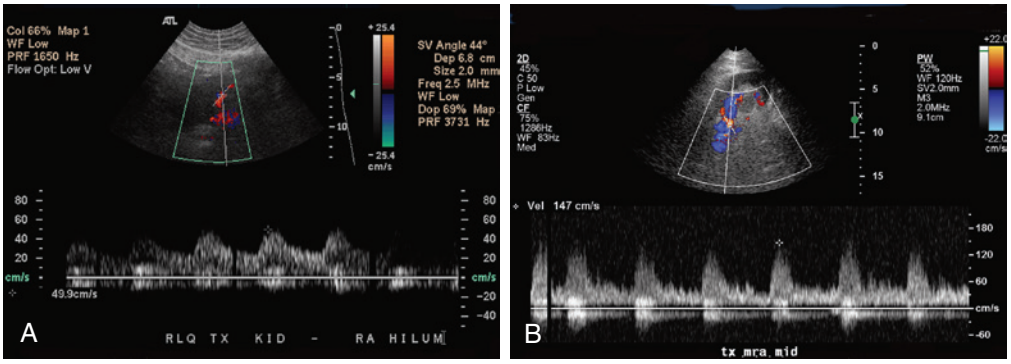


Figure 44.6 A, Doppler ultrasound scan of the renal hilum showing decreased velocity (49.9 cm/second) and loss of the early systolic peak tardus-parvus waveform. B, Normal velocity and waveform.

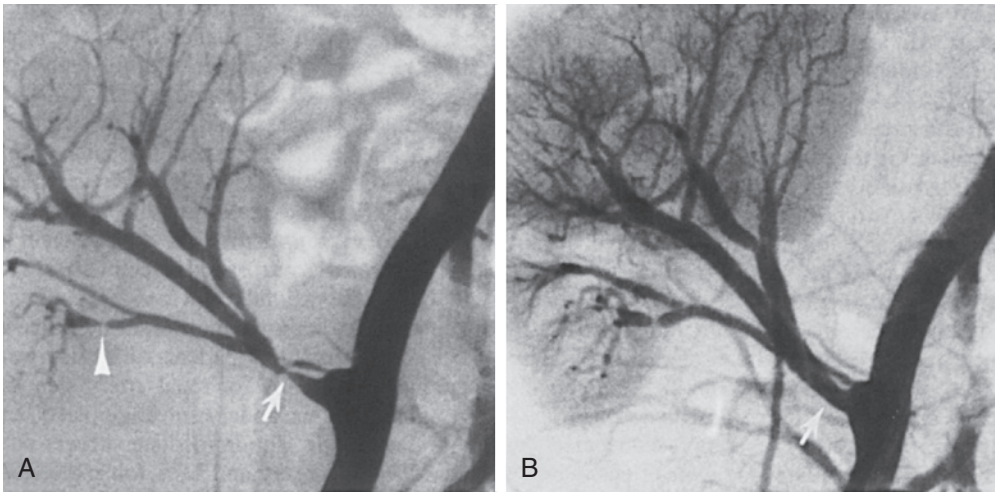


Figure 44.7 Percutaneous transluminal angioplasty of transplant renal artery stenosis. A, Severe stenosis of the proximal allograft renal artery (arrow) demonstrated on an external iliac arteriogram. The end-to-side Carrel patch anastomosis with the external iliac artery is widely patent. Also note the marked stenosis in the lower pole intrarenal branch artery (arrowhead). B, After balloon angioplasty, the proximal renal artery is widely patent (*arrow*). (With permission from Jordan ML, Holley JL, Zajko AB. Renal vascular hypertension in the transplant patient. In: Novick A, Scoble J, Hamilton G, eds. *Renal Vascular Disease*. London: WB Saunders; 1996:279.)

with turbulence. A tardus-parvus Doppler arterial waveform is also highly suggestive of TRAS (Fig. 44.6).[28] Elevated peak systolic velocities in the renal transplant artery are common in the early postoperative period and will often normalize on serial examination.[29]

Angiography remains the gold standard, although CT angiography and magnetic resonance angiography (Fig. 44.7A) can also be used to make the diagnosis. The risk of contrast administration needs to be considered in patients with marginal renal function. In some cases, carbon dioxide angiography can be used to minimize the load of nephrotoxic contrast material. Evidence has linked gadolinium contrast to the development of nephrogenic systemic fibrosis in patients receiving dialysis.[30]

Box 44.1 Causes of Transplant Renal Artery Stenosis

Recipient artery atherosclerosis
Donor artery atherosclerosis
Anastomotic stricture resulting from faulty suture technique
Arterial injury during donor nephrectomy
Kinking of the renal artery
Disparity in donor-recipient vessel size
Rejection of the donor artery
Vascular clamp injury
Perfusion pump cannulation injury

Any factor that leads to intimal injury or turbulent blood flow can result in stenosis, and clinicians should try to avoid the potential causes of TRAS listed in Box 44.1. If stenosis is diagnosed in the first postoperative month, then surgical revision of the anastomosis is usually the best option. Beyond this time period, percutaneous transluminal angioplasty (PTA) (see Fig. 44.7B) is usually the preferred treatment. When compared to treatment with PTA alone, treatment by means of stenting alone or with pre-balloon dilatation demonstrates superiority in various outcomes including patency rate (73% vs 90.4%), reintervention rate (18.9% vs 9.1%), and technical success (93.1% vs 97.1%).[31,32] Surgical correction may rarely be necessary after failed PTA or for lesions that are not approachable by angioplasty. An intraperitoneal approach to the vessels provides the best exposure. The surgical techniques for revascularization of TRAS include the following:

1. Resection of the stenotic segment and direct arterial reanastomosis
2. Transection of the transplant artery distal to the anastomosis and end-to-side reimplantation
3. Bypass with autologous saphenous vein or Gore-Tex graft
4. Open dilation
5. Vein patch angioplasty.

The immediate technical success rate of surgical correction is between 55% and 92%, with graft loss in ≤20% and a mortality rate of ≤5.5%.[33]

RENAL ARTERY THROMBOSIS

Renal artery thrombosis is most often seen in pediatric recipients. The incidence is increased in transplant recipients with thrombotic tendencies (anticardiolipin antibodies, protein C or S deficiency, or thrombocytosis). This complication can also occur in kidneys that have donor vascular disease or kidneys with multiple small arteries requiring complex bench surgical intervention before implantation (horseshoe donor kidneys, pediatric en bloc donor kidneys). Renal artery thrombosis typically occurs within the first 72 hours after transplantation.

At the time of transplant the renal allograft vessels must be carefully inspected for intimal integrity. Fine vascular suture material should be used to create an intimal approximating anastomosis. If the allograft does not perfuse properly, the vascular clamps are reapplied to the recipient vessels, the anastomosis is taken down, the kidney is flushed with chilled Ringer lactate solution containing 1000 U/L of heparin, and the anastomosis is carefully redone. If extensive reconstruction of the recipient vessel is required, the allograft should be removed and placed back in the ice-cold preservation solution on the back table. In transplants that have an increased risk of arterial thrombosis it may be helpful to give 500 U of heparin before suturing the arterial anastomosis. Continuing the heparin at 100 U per hour for the duration of the hospitalization with daily acetylsalicylic acid on discharge may also help to prevent this complication in those patients with significant risk factors.

If delayed arterial thrombosis occurs, it is rarely possible to make the diagnosis in time to salvage the graft, and this complication is usually associated with severe acute rejection. The patient may experience a sudden cessation of urine flow without any discomfort. Thrombocytopenia and hyperkalemia may occur as platelets are consumed in the graft with a sudden elevation in creatinine. The diagnosis of renal thrombosis is confirmed by ultrasonography or renal scan with no blood flow to the allograft. If the diagnosis is made immediately, then the patient is rushed to the operating room for emergency open arteriotomy and thrombectomy. Unfortunately, most grafts that sustain arterial thrombosis are lost and require allograft nephrectomy.

RENAL VEIN THROMBOSIS

Renal vein thrombosis generally occurs in the early postoperative period. Some causes of renal vein thrombosis that should be avoided include kinking or angulation of the renal vein, stenosis of the venous anastomosis, intraoperative or postoperative hypotension, hypercoagulable state, acute rejection, deep vein thrombosis with extension into the allograft, and renal vein compression by a perinephric fluid collection. Prophylactic heparinization as discussed in the previous section on arterial thrombosis may also be beneficial for transplant recipients who have an increased risk for renal vein thrombosis. If venous thrombosis occurs intraoperatively, the allograft will appear cyanotic and swollen. A clot may be palpable in the renal vein.

Thrombectomy and revision of the anastomosis should be attempted as in arterial thrombosis. The vascular clamps should be carefully reapplied so that a segment of the thrombus is not dislodged into the systemic circulation. Delayed renal vein thrombosis is usually diagnosed by Doppler ultrasonography and may be confirmed by renal scan or venography. Late renal vein thrombosis (occurring >4 weeks after transplantation) is usually a result of propagation of deep vein thrombosis into the renal vein. Thrombolytic therapy with intravenous streptokinase or anticoagulation may occasionally be useful. The diagnosis of late venous thrombosis is usually made after a period of prolonged allograft ischemia, and nephrectomy is indicated.

DEEP VEIN THROMBOSIS AND PULMONARY EMBOLISM

Pulmonary embolism is the most common preventable cause of death among hospital patients in the United States.[34] Estimates of venous thromboembolic event incidence within the first year following kidney transplant vary widely, but most large series estimate the rate at 1–3%.[35] Variation in reported

rates is likely due to variable methods of prophylaxis and detection. Possible risk factors for venous thromboembolism include stasis from clamping of the vein, endothelial injury from creation of the vascular anastomosis, pelvic dissection, diabetes, calcineurin inhibitors, immobility, elevated homocysteine level, and decreased venous emptying secondary to urinoma, hematoma, lymphocele, or positioning of the kidney. We recommend placement of pulsatile compression stockings before the induction of anesthesia and removal of these stockings when the patient is ambulating. Chemoprophylaxis with subcutaneous heparin may be added for high-risk recipients. Low-molecular-weight heparins may be considered but should be used with extreme caution as some of these are renally cleared. One alternative is dalteparin, which has been successfully used and is not dependent on renal function for metabolism.[36]

LYMPHOCELE

Lymphatic collections are usually found medial to the renal allograft and may occur in 36% of transplants.[37] The lymphatic collection arises from the lymphatics surrounding the iliac vessels that are divided during mobilization or renal hilar lymphatics of the donor kidney. Some lymphoceles may produce pain, ureteral obstruction, voiding symptoms, and renal or iliac vein compression leading to deep vein thrombosis or leg swelling. The diagnosis is confirmed by ultrasound examination (Fig. 44.8) and aspiration of the fluid using sterile technique. Lymphatic fluid is usually clear with a high lymphocyte count, high protein content, and creatinine concentration similar to that of serum.

Small, asymptomatic lymphoceles do not require treatment. Aspiration alone may resolve the problem, but repeated aspiration is discouraged because it may lead to infection and rarely results in permanent decompression. Percutaneous closed-system catheter drainage with instillation of sclerosing agents, such as povidone-iodine (Betadine)[38] or fibrin glue,[39] has been successful. Loculated lymphoceles, collections adjacent to the renal hilum, and those that are inaccessible for safe puncture are best treated by marsupialization into the peritoneal cavity. This procedure may be accomplished by a laparoscopic or open surgical approach.[37,40] The transplant ureter, which is often incorporated into the wall of the lymphocele, must be identified and carefully preserved. A cystoscopically placed ureteral stent or intraoperative ultrasound scan may be beneficial. The peritoneal opening must be large enough to prevent bowel herniation. Omentum is usually placed in the opening to prevent closure.

The incidence of lymphoceles can be reduced by minimizing the pelvic dissection and ligating lymphatics. Avoiding the immunosuppressant agent sirolimus in the early postoperative period may also help to reduce the incidence of this complication. Additionally, placing a drain at the end of the procedure and leaving it for the initial postoperative course has been shown to reduce lymphatic collections.[41]

ARTERIOVENOUS FISTULA

In renal allografts, arteriovenous fistula formation most commonly follows renal transplant biopsy. Other causes of arteriovenous fistula include trauma, infection, rupture of an aneurysm, and injury to segmental renal vessels before organ recovery. In these latter cases, segmental renal infarction of the parenchyma subtended by the injured vessel may also lead to urine leak from the underlying calyx. An arteriovenous fistula may manifest with hypertension, hematuria, or a bruit over the allograft. The diagnosis is confirmed by color duplex ultrasound examination (Fig. 44.9) or angiography (Fig. 44.10). Most post-biopsy fistulas are small and resolve spontaneously. Localized pressure with the ultrasound probe may diminish flow enough to allow localized thrombosis. Angiography with selective embolization of the feeding vessel is the treatment of choice for persistent clinically significant fistulas.[42] The incidence of arteriovenous fistula may be reduced by correcting the bleeding time and platelet count before performance of ultrasound-guided biopsy of the renal allograft cortical tissue.[43]

Graft Rejection

Only kidneys from identical twin donors have no risk of rejection, require no immunosuppressive medication, and may continue to function for >40 years. Almost all other

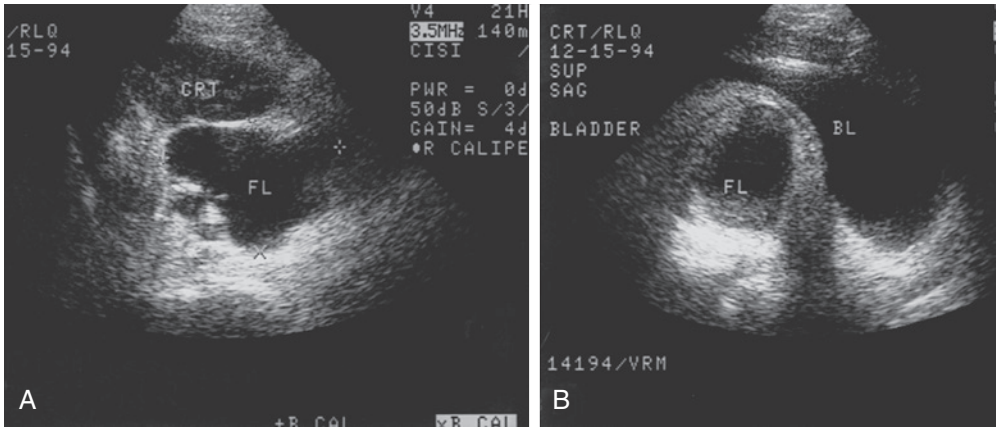


Figure 44.8 Renal allograft ultrasound with a lymphocele. A, The lymphocele (FL) is medial to the renal transplant (CRT). B, The lymphocele extends into the pelvis and displaces the bladder (BL). Attempted sclerosis of this lymphocele with povidone-iodine (Betadine) initially failed, but treatment was successful with an open peritoneal window procedure.

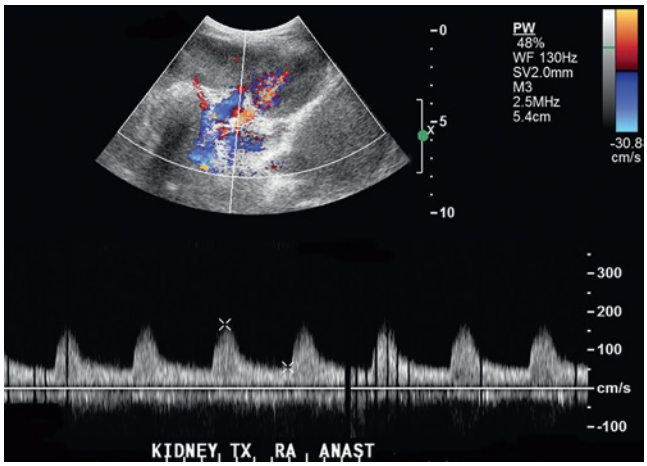


Figure 44.9 Doppler ultrasound scan of renal allograft after biopsy. Note the speckling of colors within the upper region, a finding suggestive of a fistula because blood is flowing in various directions.

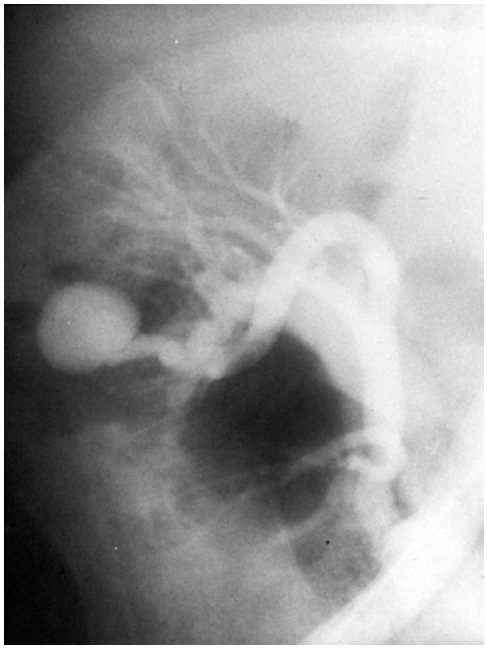


Figure 44.10 Angiogram of an arteriovenous fistula after renal allograft. Note visualization of the renal vein before the nephrogram phase. This fistula was treated with selective embolization.

donor kidneys eventually succumb to rejection and require immunosuppression. Allograft rejection is classified into three major categories: hyperacute, acute, and chronic.

Hyperacute rejection usually begins immediately after perfusion. The transplanted kidney, after initially perfusing well, may become cyanotic, soft, and edematous. One must exclude other causes of insufficient arterial blood supply including positional kinking of the vessels, intimal flap, or hypotension. The diagnosis is confirmed by an intraoperative biopsy of the kidney that shows polymorphonuclear leukocytes in the glomeruli and peritubular capillaries with widespread vascular thrombosis. This type of rejection results from preformed cytotoxic antibodies reactive to endothelial cells of the graft.

Hyperacute rejection can usually be prevented by testing the recipient serum for antibodies reactive to donor lymphocytes with a cross-match test. This test is typically performed before each renal transplantation. Recipients with a positive cross-match test result or blood type incompatibility have undergone successful transplantation with plasmapheresis, intravenous immunoglobulin, and potent immunosuppression. Treatment of hyperacute rejection is disappointing and is generally associated with graft loss.

Acute rejection occurs in 10–40% of allografts within the first year after transplantation.[44,45] With current immunosuppression, the only presenting sign is usually a rise in the serum creatinine level. The diagnosis is confirmed by allograft biopsy. The differential diagnosis includes dehydration, ischemia reperfusion injury, drug nephrotoxicity, obstruction, and pyelonephritis. Acute rejection is often the result of an insufficient immunosuppression regimen or poor patient compliance. New methods of monitoring the immune response may allow the clinician time to increase immunosuppression and reverse the process before significant damage to the allograft occurs.[46] Approximately 90% of acute rejections are cell mediated and are characterized by lymphocytic invasion of the interstitium and tubular epithelium. Ten percent of acute rejections show evidence of antibody-mediated rejection, characterized by complement deposition (C4d) in the peritubular capillaries. Vascular rejection signifies arterial inflammation and can result from either cell-mediated or antibody-mediated rejection. Standardized criteria for grading renal allograft biopsies have been developed and are used to guide additional immunosuppressive therapy.[47]

Acute rejection within the first year after transplantation can be successfully reversed approximately 80% of the time.[2] Acute cellular rejection is treated by high-dose methylprednisolone, by antilymphocytic antibodies, or by increasing the dosage of calcineurin inhibitor medications. For antibody-mediated acute rejection, most clinicians favor rapid removal of the circulating antibodies by plasmapheresis and the neutralization of the remaining antibodies with intravenous immunoglobulin.

Chronic rejection is identified in most renal transplants after a few years. Renal allograft biopsies show evidence of accelerated atherosclerosis, interstitial fibrosis, and tubular atrophy. The pathogenesis is not fully understood but both antigen-dependent and antigen-independent mechanisms of vascular injury are implicated. The serum creatinine concentration slowly increases until the allograft fails. Although immune factors including acute rejection play a role in the development of chronic rejection, the newer term *chronic allograft nephropathy* more accurately describes the multifactorial nature of this disease. Hypercholesterolemia, hypertension, immunosuppression nephrotoxicity, ischemia reperfusion injury, and infection have all been associated with the same pathologic findings. Many clinical trials are now being designed to determine whether this process can be stopped or prevented. Increasing immunosuppressive treatment is usually not advised.

References

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Chapter 44 Questions

1. The percentage of patients with end-stage renal disease who are candidates for renal transplantation in the United States is approximately:
   a. 10%
   b. 20%
   c. 40%
   d. 80%
   e. 100%

2. An anuric patient on hemodialysis for 3 years has bloodshot eyes and complains of itching. A likely cause is:
   a. Allergic reaction to heparin
   b. Glaucoma
   c. Uncontrolled hypertension
   d. Poor adherence to diet recommendations
   e. Excessive fluid consumption

3. How should post-biopsy fistulas initially be treated?
   a. Medications to control hypertension
   b. Fresh frozen plasma and platelet transfusion
   c. Angiography and embolization
   d. Open exploration and repair
   e. Allograft nephrectomy

4. Antibody mediated rejection is confirmed by renal allograft biopsy with the histologic finding of:
   a. Lymphocytic infiltration of renal tubules
   b. Dense deposits in the glomerulus
   c. Complement fragment C4d deposition in peritubular capillaries
   d. Thickening of Bowman's capsule
   e. Arteriolar sclerosis of the arcuate arteries

5. The most common etiology of allograft failure within the first year following renal transplantation is:
   a. Cardiac event resulting in death of patient
   b. Graft thrombosis
   c. Acute rejection
   d. Recurrence of diabetic nephropathy
   e. Hypertensive nephrosclerosis

6. Flushing of the in situ allograft artery following completion of the venous anastomosis with either Collin's or UW solution can result in:
   a. Decreased risk of acute tubular necrosis
   b. Decreased risk of delayed graft function
   c. Increased risk of heart block
   d. Increased risk of hypokalemia
   e. Increased risk of graft thrombosis

7. Immunosuppressive regimens commonly used in renal transplantation are associated with which of the following?
   a. Decreased rates of malignancy
   b. Improvement in glycemic control
   c. Increased risk of ischemia stroke
   d. Diminished risk of viral and bacterial infections
   e. Nephrotoxicity

8. A 27-year-old female presents with hydronephrosis of her allograft and an elevated serum creatinine 9 weeks following deceased donor renal transplant. Her bladder is decompressed on ultrasound. A percutaneous nephrostomy tube is placed and an antegrade nephrostogram demonstrates a 2.2-cm distal ureteral stricture. The most appropriate management of the ureteral stricture is:
   a. Internalization of the nephrostomy tube with periodic stent exchanges
   b. Cystoscopy with balloon dilation of the ureteral stricture and stent placement
   c. Antegrade endoscopy with laser incision of the ureteral stricture and stent placement
   d. Resection of the ureteral stricture with reimplantation into the bladder and stent placement
   e. Conversion of the nephrostomy tube to a nephroureteral stent with follow-up antegrade nephrostogram

9. Renal artery stenosis is suggested by transplant duplex ultrasonography when the following finding is identified:
   a. Mid renal artery systolic velocity of 170 cm/s
   b. Intrarenal resistive index of 0.7
   c. Tardus-parvus arterial waveform
   d. Anastomotic end-diastolic velocity of 20 cm/s
   e. Iliac artery peak systolic velocity of 140 cm/s

10. The most common form of early rejection in renal transplant recipients is:
    a. Hyperacute rejection
    b. Cell-mediated acute rejection
    c. Antibody-mediated acute rejection
    d. Acute tubular necrosis
    e. Vascular rejection

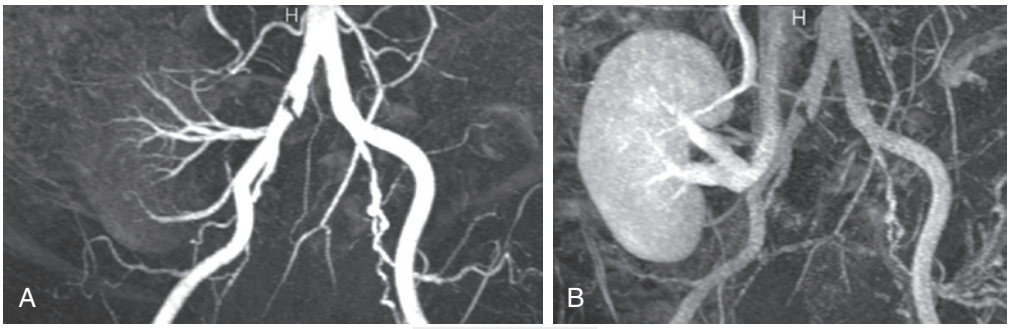
Case Studies

CASE 1

A 62-year-old male with a past medical history significant for hypertension undergoes an uneventful living unrelated renal transplant into the right iliac fossa. Postoperatively he complains of fatigue and cramping in his right buttock, thigh, and calf that is brought on with ambulation over distances of about 100 feet. The pain is relieved with rest. Prior to his transplant he was able to walk 1.5 miles without difficulty. His vitals are unremarkable. His serum creatinine has trended down following surgery and is now at 1.4 mg/dL. Case Fig. 44.1.

1. Which physical examination findings are consistent with this patient's symptoms?

a.	Right pulses: Fem- 1+, PT- 2+	Left pulses: Fem- 2+, PT- 2+
b.	Right pulses: Fem- barely palpable, PT- 2+	Left pulses: Fem- 2+, PT- 2+
c.	Right pulses: Fem- barely palpable, PT- absent	Left pulses: Fem- 1 +, PT- absent
d.	Right pulses: Fem- barely palpable, PT- absent	Left pulses: Fem- 2+, PT- 2+
e.	Right pulses: Fem- 2+, PT- absent	Left pulses: Fem- 2+, PT- 2+



Case Figure 44.1

2. Based on the patient's symptomatology, where would you expect to find a lesion?
   a. Transplant renal artery
   b. Right common iliac artery
   c. Right internal iliac artery
   d. Right external iliac artery
   e. Right superficial femoral artery

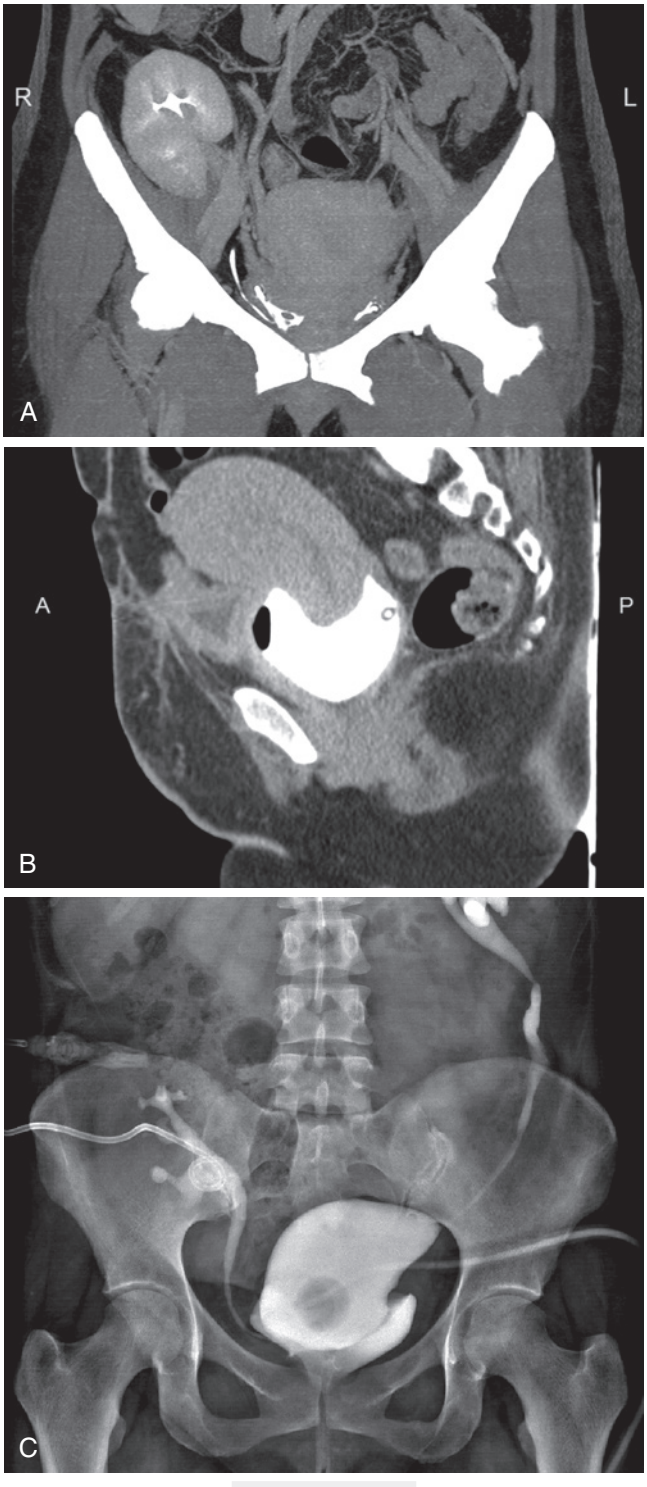
3. What imaging study is most likely to yield a causative finding while avoiding risk of toxicity to the transplant kidney?
   a. Angiography (aortogram with runoff)
   b. CT abdomen/pelvis with IV contrast
   c. MR angiogram abdomen/pelvis with gadolinium
   d. Transplant duplex ultrasound
   e. MAG3 with flow and function

4. An MR angiogram of the abdomen and pelvis is obtained with representative images shown (see Case Fig. 44.1). The most likely explanation for the cause of this patient's vascular lesion is:
   a. Proximal extension of a renal arterial thrombosis
   b Renal vein thrombosis with proximal extension
   c. Mycotic infection of an atherosclerotic lesion
   d. An intraoperative injury resulting from a vascular clamp
   e. Renal arterial stenosis with turbulent flow proximally

CASE 2

A 41-year-old female presents for surgical evaluation as a renal transplant candidate. Her urologic history is notable for a urogenital sinus treated with bladder neck reconstruction, continent urinary diversion, and urethral reconstruction. She has had progressively worsening kidney function due to her congenital urologic anomalies and is now on hemodialysis. She still makes urine and denies urinary incontinence, incomplete emptying, or recurrent urinary tract infections.

1. In preparation for her renal transplant, which study/studies would be most beneficial for identifying physiologic and/or anatomic abnormalities that may negatively impact the outcome of her surgery (Case Fig. 44.2)?
   a. MAG3 scan
   b. Video urodynamics
   c. Cystoscopy
   d. CT abdomen/pelvis
   e. Uroflow and post-void residual



Case Figure 44.2

2. You are about to begin the ureteral reimplantation portion of the transplant and are considering the various surgical techniques available. Which form of ureteral reimplantation has been demonstrated to have the lowest complication rate?
   a. Unstented Taguchi
   b. Unstented Lich-Gregoir
   c. Stented Polatano-Leadbetter
   d. Stented Taguchi
   e. Stented Lich-Gregoir

3. A ureteral reimplant is performed without the aid of bladder distention as a catheter could not be placed preoperatively due to a very narrowed introitus and urethral meatus, which is high and posterior to her pubic bone. Her pelvis is scarred from her prior reconstructive surgery. A suprapubic tube is used to drain her bladder postoperatively. One month after surgery her suprapubic catheter is removed and she notices progressive onset of urinary incontinence that is not preceded by urgency, cough, or sneeze. As part of her workup a CT urogram was obtained with a representative coronal and sagittal image is shown (See Case Fig. 44.2).

   Based on these images in Case Fig. 44.2, what is the most definitive treatment for this patient?
   a. Ureteral reimplantation
   b. Initiation of clean intermittent catheterization
   c. Timed voiding
   d. Placement of suprapubic catheter with periodic exchanges
   e. Placement of percutaneous nephrostomy tube and Foley catheter

Answers

1. **b.** In the United States there are approximately 450,000 patients on dialysis and 100,000 candidates on the national deceased donor waiting list for kidney transplantation (22%). Patients with a living donor are generally listed for a deceased donor organ as a back-up plan.
2. **d.** Patients with renal failure are not able to eliminate potassium and phosphorus. A common problem for dialysis patients is hyperphosphatemia when they do control the consumption or GI elimination with binders. The deposition of calcium phosphate crystals leads to irritation of the conjunctiva and skin. Deposition in small blood vessels can lead to tissue necrosis or calciphylaxsis when the calcium × phosphorus product is greater than 70.
3. **a.** Approximately 70% of post-biopsy fistulas close spontaneously within 18 months.
4. **c.** Complement deposition in the peritubular capillaries by immunofluorescence and detection of donor specific antibody in the serum is diagnostic of antibody-mediated rejection. This is an important distinction since the treatment is different than acute cell-mediated rejection.
5. **a.** Cardiac events resulting in death (with a functioning allograft) are the most common cause of allograft failure within the first year following renal transplant.
6. **c.** Both Collin's and UW preservation solutions contain high levels of potassium. Direct infusion into a recipient's intravascular space can result in hyperkalemia, heart block, and cardiac arrest.
7. **e.** Modern immunosuppressive regimens utilizing calcineurin inhibitors (cyclosporine, tacrolimus) and steroids have side effect profiles which include increased risk of malignancy and infections, glucose intolerance, and hyperlipidemia. Although administered to prevent rejection and subsequent allograft rejection, these regimens can also lead to nephrotoxicity resulting from renal vasoconstriction and chronic interstitial fibrosis.
8. **d.** Strictures >2 cm in length should be primarily managed with excision and reimplantion. Additional techniques such as a Boari flap or psoas hitch may be utilized to facilitate reimplantation. Endoscopic management of transplant ureteral strictures is best reserved for distal ureteral strictures <1 cm in size. Direct vision internal ureterotomy, typically with a laser, is the preferred endoscopic technique.
9. **c.** Renal artery peak systolic velocities of >200 cm/s, turbulent renal artery blood flow, and a tardus-parvus Doppler arterial waveform are all suggestive of transplant renal artery stenosis. A tardus-parvus Doppler arterial waveform appears as a small amplitude waveform with a prolonged systolic rise when compared to the normal arterial waveform, which has a sharp systolic upstroke peak.
10. **b.** Cell-mediated acute rejection is the most common form of early rejection in renal transplant recipients and is confirmed with a biopsy. This form of rejection is characterized by lymphocytic invasion of the interstitium and tubular epithelium.

CASE 1

1. **d.** This patient has both buttock and calf claudication and therefore would be expected to have diminished femoral and pedal pulses on the affected side. He had no symptoms of left lower extremity claudication and therefore would be expected to have a palpable left femoral and tibial pulse on exam.
2. **b.** The right common iliac artery is where you would expect to find an arterial lesion based on this patient's symptoms of buttock, thigh, and calf claudication. Thigh and buttock claudication predominate when an arterial lesion is present in the aortoiliac area as the internal iliac artery must also have diminished blood flow to produce these symptoms. Lesions of the external iliac artery and superficial femoral artery will spare the buttock and typically cause only thigh or calf pain. A lesion of the transplant renal artery would be unlikely to result in symptoms of claudication.
3. **c.** An MR angiogram abdomen/pelvis has a high sensitivity for detection of intravascular lesions while avoiding the risk of contrast-induced nephropathy to the newly transplanted kidney. Additionally, MR angiogram avoids the need for intravascular access required for angiography and is not operator dependent like a duplex ultrasound.

While duplex ultrasound may suggest the location of a vascular lesion it will not define the anatomy as clearly as an MR angiogram. A MAG3 scan would not provide you with detailed intravascular anatomy.

4. **d.** These images (Case Fig. 44.1) demonstrate focal dissection in the middle part of the right common iliac artery with an intimal flap. The most likely explanation for this dissection is an intraoperative vascular clamp injury. Vascular clamp injuries following renal transplant are rare and can present with lower extremity claudication or remain asymptomatic with only mild graft dysfunction noted on labs. Diagnosis is suspected with an abnormal duplex ultrasound and can be confirmed with an MR angiogram, CT abdomen/pelvis with contrast, or angiography. If severe peripheral vascular disease is noted intraoperatively, then noncrushing Fogarty shodden clamps can provide vascular control with less risk of intimal injury.

CASE 2

1. **b.** In patients with complex urologic history, urodynamics may further clarify the type of lower urinary tract dysfunction and offer the opportunity for medical or surgical optimization prior to renal transplant. Ensuring optimal bladder function prior to transplant may help minimize any negative influence on graft function.
2. **e.** A stented Lich-Gregoir ureteral reimplant has been shown to have the lowest complication rate in terms of urine leaks, urine obstruction, and hematuria.
3. **a.** The bladder is seen anterior to the uterus in the sagittal view and the vagina is actually filling with contrast. Contrast was retained in the vagina due to her narrowed introitus resulting from prior surgeries. At the time of her transplant the ureter was reimplanted into the vagina, and definitive management involves reimplantation into the bladder. Bladder distention typically aids in the identification of the bladder wall; however, in this case the maneuver could not be performed due to inability to place a catheter preoperatively. This patient underwent ureteral reimplantation and the VCUG (Case Fig. 44.2C) shows contrast traveling down the ureter and into the bladder. During the voiding phase contrast can be seen refluxing up her transplant ureter and left native ureter. Contrast is also pooling into her vagina. She was continent of urine following her reimplantation.

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45 Complications of Conduit Urinary Diversion

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CHAPTER OUTLINE

Preoperative Considerations
Selection of Bowel Segment
Selecting the Length of Bowel
Selecting the Site of Stoma
Extracorporeal Versus Intracorporeal Laparoscopic Urinary Diversion
Complications
Conduit
Calculi
Malignant Disease
Bowel
Stoma
Parastomal Hernia or Prolapse
Stomal Stenosis
Ureterointestinal Anastomosis
Ureteroileal Anastomotic Leak
Anastomotic Strictures
Fate of the Kidney
Pyelonephritis and Renal Damage
Refluxing Versus Nonrefluxing Anastomoses
Double-barreled Wet Colostomy
Bacteriology of the Ileal Conduit
Other Potential Complications
Chapter 45 Questions and Answers

KEY POINTS

1. In performing radical cystectomy, the urinary diversion is the most common source of morbidity.
2. Careful selection of the bowel segment based upon mesenteric arcades is essential in avoiding bowel ischemia or bowel anastomotic leak.
3. In preparing the bowel, the distal mesenteric incision will provide the greatest length to the stoma in reaching the skin.
4. Stomal preparation prior to abdominal wall transposition may avoid stomal retraction.
5. Care of the stoma, stomal hygiene, and periodic inspection by an enterostomal therapist may help the patient avoid eventual stomal stenosis.
6. Both Bricker- and Wallace-style ureterointestinal anastomotic techniques can be associated with low morbidity, but a tension-free anastomosis with careful attention to ureteral vascularity is essential for success.

In 1851 Sir John Simon of London attempted open ureterosigmoidostomy in dogs. He reported that the operation was "almost always fatal, and it was plain that the peritoneum would be exposed to much hazard."[1] Although urinary diversion can be dated back to 1851, it was not until 1950 that Bricker[2] reported on the use of ileum for "bladder substitution after pelvic evisceration." Although ileal conduit is the simplest and most popular of diversions, complications are frequent.[3] The surgeon should discuss the options as well as the advantages and disadvantages of conduit and continent diversion with the patient well before the operative day. Critical factors to consider include the patient's age and performance status, manual dexterity, body habitus, motivation and desires, expected long-term functional status, bowel condition, bowel length, prior surgery or radiation, and renal reserve.

Construction of the urinary conduit carries the potential for a great number of unforeseen events. Complications can be divided into two categories, early (≤30 days of the surgical procedure) and late. The rate of early complications has been reported to range from 20% to 56%,[4] and such complications include intestinal obstruction, fistula formation, leakage from the ileal-ileal or ureteroileal anastomosis, wound infection, wound dehiscence, loop necrosis, and pyelonephritis. The incidence of late complications reportedly ranges from 28% to 81%,[4] and these complications include intestinal obstruction, pyelonephritis, renal deterioration, ureteroileal strictures and obstruction, stomal stenosis, parastomal herniation, calculi, metabolic abnormalities, and the development of carcinomas.

In evaluating quality of life issues, Turner and colleagues[5] found that 88–95% of patients were satisfied overall,

whereas 17–19% of patients were bothered by impaired body image. With regard to sexuality, 30% of patients reported decreased libido, whereas 20% felt less sexually attractive.[6] Hart and associates[7] reported frequent difficulty in caring for the collection device in 57% of their patients who had undergone ileal conduit procedures. Dutta and colleagues[8] found that 85% of patients undergoing ileal conduit would make the same choice of urinary diversion again.

The choice of urinary diversion remains controversial from a quality-of-life perspective. A 2005 meta-analysis by Porter and Penson[9] found insufficient evidence to conclude that one form of urinary diversion is superior to another. A more contemporary meta-analysis including five additional studies, three[11–13] of which demonstrated an improved quality of life among patients undergoing orthotopic neobladder rather than ileal conduit, led Ghosh and Somani to conclude that patients with orthotopic neobladder had significantly improved quality of life. An ileal conduit remains, however, an appropriate and often preferable option to orthotopic neobladder, due to individual patient preferences and selection considerations, such as renal function and a patient's ability to comply with neobladder maintenance.

In our experience, patients undergoing conduit diversion often experience a reduced quality of life, or depression, in the initial period following surgery, largely due to a perception of altered body image and limitation of normal routine activities. With time, individuals seem to adapt and by 1–2 years following the procedure, most patients do not greatly complain of any limitations or altered self-perception. Those individuals who have chronic difficulties in caring for the stoma, or experience poor appliance fit and urine leakage, will generally have a harder time adapting and remain depressed. Among patients with preoperative debilitation due to bleeding, pain, or voiding difficulties, conduit diversion may greatly improve quality of life and outlook, even in the early postoperative period.

Preoperative Considerations

Complications related to major intraabdominal surgery include those secondary to anesthetic, cardiac, pulmonary, and thromboembolic events. Prevention of such complications is discussed elsewhere in the text. Preoperative patient selection and proper evaluation by a cardiologist or pulmonologist may be necessary.

In today's age of managed care, most patients undergo bowel preparation at home. Wolff and colleagues[14] found little difference between aggressive antibiotic preparation and a minimal preparation of enemas, dietary restrictions, and mechanical lavage. This finding suggests that aggressive preparation can be safely avoided, thus reducing the risk of perioperative colitis. We routinely use a 2-day bowel preparation in which patients are started on a clear liquid diet 2 days before the surgical procedure. Magnesium citrate is prescribed for 2 days preoperatively along with two saline laxative (Fleet) enemas the night before the operation. Alternatively, 1 day preoperatively, patients are asked to drink ≤1 gallon of polyethylene glycol and electrolyte solution (GoLYTELY) until the stool is clear. The classic use of antibiotic preparation is discouraged.

SELECTION OF BOWEL SEGMENT

Based on early experience, the use of jejunum in urinary reconstruction has fallen out of favor. Although functional results are not significantly different from those seen with ileum, tremendous metabolic complications arise secondary to water and salt loss. Golimbu and Morales[15,16] used both canine and clinical models to evaluate jejunal conduits. These investigators reported on a series of 30 jejunal conduits used in patients with a history of prior radiation, multiple pelvic surgical procedures, or poor condition of the distal ureters, ileum, or colon. They found that the major complications with use of jejunum were electrolyte abnormality and water loss. However, the resulting hypochloremic, hyponatremic, and hyperkalemic metabolic acidosis, generally accompanied by dehydration, usually responded to increased salt and fluid intake. Despite these findings, jejunum is rarely used today because of the great consequences of fluid shifts, and this method should be considered only when no other option is viable.

The use of ileum and colon has similar functional and metabolic outcomes. In general, those patients with metabolic abnormalities are found to have hyperchloremic metabolic acidosis secondary to luminal bicarbonate loss and active hydrogen ion or ammonium reabsorption.[17] Factors influencing the severity of the metabolic abnormality include the contact time of urine and bowel (conduit length), the drainage of the conduit (adequate stoma), and the underlying renal function of the patient. Other metabolic conditions include encephalopathy from elevated ammonia, weakness from hypocalcemia, neuromuscular dysfunction from hypomagnesemia, and osteomalacia or growth delay in children. Patients with osteomalacia specifically develop bony pain, muscle weakness, decreased phosphate, increased alkaline phosphatase, and excess osteoid in the bone. The physiologic features and management of the metabolic abnormalities accompanying ileal or colon diversion are discussed in detail in Chapter 5. In general, the acidosis is easily treated by one of a variety of medications.[18]

Although functional and metabolic results of colon and ileal conduits are generally similar, Mogg[19] initially described the technique of the colon conduit to be superior to that of ileal conduit because of the thicker musculature, infrequent peristalsis, and the need for less intraperitoneal manipulation. In his review of 48 cases, Mogg found complications in 16 patients: four patients developed stones, two developed ureteral stenosis, eight had stomal ulceration, and two developed urinary peritonitis.

Morales and Golimbu[20] evaluated 46 colon conduits, of which 39 were constructed using transverse colon. In their study, these investigators observed a 15% mortality rate. Early complications included intestinal obstruction in three (6.5%), intestinal anastomotic leak in two (4%), and bilateral ureteral obstruction in one (2%). Late complications included acute pyelonephritis in eight (17%) and stomal prolapse in six (13%), with four (8.5%) of these patients requiring surgical repair. In addition, six patients (13%) had ureterointestinal anastomotic obstruction. In evaluating the patients' upper urinary tracts, 32% of normal kidneys showed deterioration postoperatively, 37% of preoperatively abnormal renal units improved, and 25% of preoperatively abnormal renal units deteriorated. The

investigators used an intraluminal nipple to achieve an antirefluxing mechanism, and no patient with antirefluxing ureters developed renal damage.

Complication rates with ileal conduit diversion have been similar to those observed with colon conduit. Jahnson and Pedersen[21] reported on 124 patients with ileal conduits followed for ≤20 years. Of the 124 patients, 48% had early complications including urine or intestinal anastomotic leaks, urinary or intestinal obstruction, wound dehiscence, infection, or cardiovascular misadventure. These investigators noted a 6% mortality rate in the perioperative period (four deaths from septicemia, two from myocardial infarction, and one from uremia). Jahnson and Pedersen also found an association between preoperative radiation therapy and the rate of wound infection. In addition, the investigators reported a late complication rate of 52%, including 22% of patients with ureteroileal obstruction or stricture.

Singh and associates[22] evaluated 93 patients undergoing ileal conduit for benign disease and looked at the complication rate after an average of 5 years. These investigators reported a mortality rate of 2.1%. Complications again were related to the stoma (31%); 10% of patients developed a parastomal hernia, and 4.3% developed stomal retraction and stenosis. These investigators reported complications of the ureteroileal anastomosis in 7% of the patients. In addition, 34% of patients had upper urinary tract dilatation, 10% with bilateral changes.

More recently, Shimko and associates[23] evaluated the records of 1057 patients who had undergone radical cystectomy with primarily ileal conduit diversion (1.1% received colon) with a median follow-up of 6.3 years. They found an average of 2.3 complications per patient, occurring at a median of 1.1 years postoperatively. Patients developed bowel complications in 20.3% of cases, 20.2% had renal complications, 13.9% developed a parastomal hernia, 2.1% developed stomal stenosis, and 9% of patients required a reoperation. The authors also noted that stone-related complications occurred in 15.3% of patients who underwent conduit diversion.

In general, it appears that ileal and colon conduit diversions have similar outcomes. Because of the technical ease of ileal diversion, this remains the segment of choice. The decision to use colon is usually based on the condition of the ileum or distal ureters as a result of pelvic irradiation or prior surgical intervention, the length of ureter resected at the time of operation, or the presence of inflammatory bowel disease in the terminal ileum. When the surgeon performs en bloc resection of the colon or rectum, a sigmoid colon conduit may eliminate the need for two bowel anastomoses, or any anastomosis if a colostomy is to be constructed. Finally, if an upper abdominal stoma is required, the transverse colon can be used to reduce the technical difficulty associated with bowel mobility. In patients undergoing colon conduit, barium enema should be adequate to rule out the possibility of colonic malignant disease or other abnormalities. In patients undergoing ileal diversion, barium enema is not necessary, but it may be helpful in ruling out potentially obstructive distal abnormalities.

An effort is underway to reduce concerns regarding bowel-related complications of urinary diversion through tissue engineering. Bivalacqua and colleagues[24] have demonstrated successful implantation of tissue-engineered neourinary conduits (NUC), produced by seeding smooth muscle cells onto a PLGA scaffold, in a porcine model. As a result of these promising results, multicenter phase I trials are underway to assess the safety of NUC in humans. Many questions regarding the use of tissue-engineered conduits remain, however, including which materials are best used to construct these conduits, and which surgical techniques are best utilized to maintain conduit blood supply and patency.

SELECTING THE LENGTH OF BOWEL

As mentioned previously, the length of bowel used can be a critical determinant of the severity of metabolic abnormality associated with the pouch. A length of 10–12 cm serves as a general guideline. In obese patients with a large amount of abdominal wall to traverse, a longer segment should be isolated. Lengthening and mobilizing the distal conduit can be achieved either through aggressive division of the mesentery (with care taken to preserve the proximal ileocolic branch) or, as a preferred method, resection of a segment of bowel immediately distal to the conduit (Fig. 45.1). Another option in the management of a short distal mesentery is the use of a Turnbull loop stoma. In this technique, a "knuckle" of the distal conduit is brought through the fascial opening. The antimesenteric border is incised, thus allowing circumferential maturation without any tethering from the distal mesentery.

The surgeon should pay careful attention to the anatomic lie of the conduit after maturation of the stoma. The intraabdominal portion of the conduit should be relatively straight, with no kinking or twisting to impair luminal drainage. A red rubber catheter left in the length of the conduit can allow the conduit to heal in a straight fashion.

In individuals with a thin abdominal wall or small body habitus, as short a segment as possible should be used. Preserving good length of the ureters can allow the ureterointestinal anastomoses to "rise" along the lateral abdominal wall and can thereby minimize the intraabdominal length of the conduit. Tension on the ureteroileal anastomoses can be avoided by fixation of the proximal segment of the conduit to the sacral promontory or by a lateral retroperitoneal incision.

In patients with impaired renal reserve, as noted by elevated serum creatinine concentration or creatinine clearance <50 mL/minute, the surgeon should make every effort to limit the conduit to as short a length as required by the abdominal wall thickness. Although cutaneous ureterostomy is an option in patients with renal insufficiency, it is generally preferable to interpose at least a short segment of bowel to avoid the stomal retraction and stenosis seen in cutaneous ureterostomy. Even with significant renal impairment, the patient should have only limited worsening of renal function if the conduit is constructed with the intention of keeping the transit time of urine as short as possible.

SELECTING THE SITE OF STOMA

Selection of the stoma site is probably the most important preparatory step for conduit surgery. Ultimately, the stoma predicts the long-term success or failure of the operation.

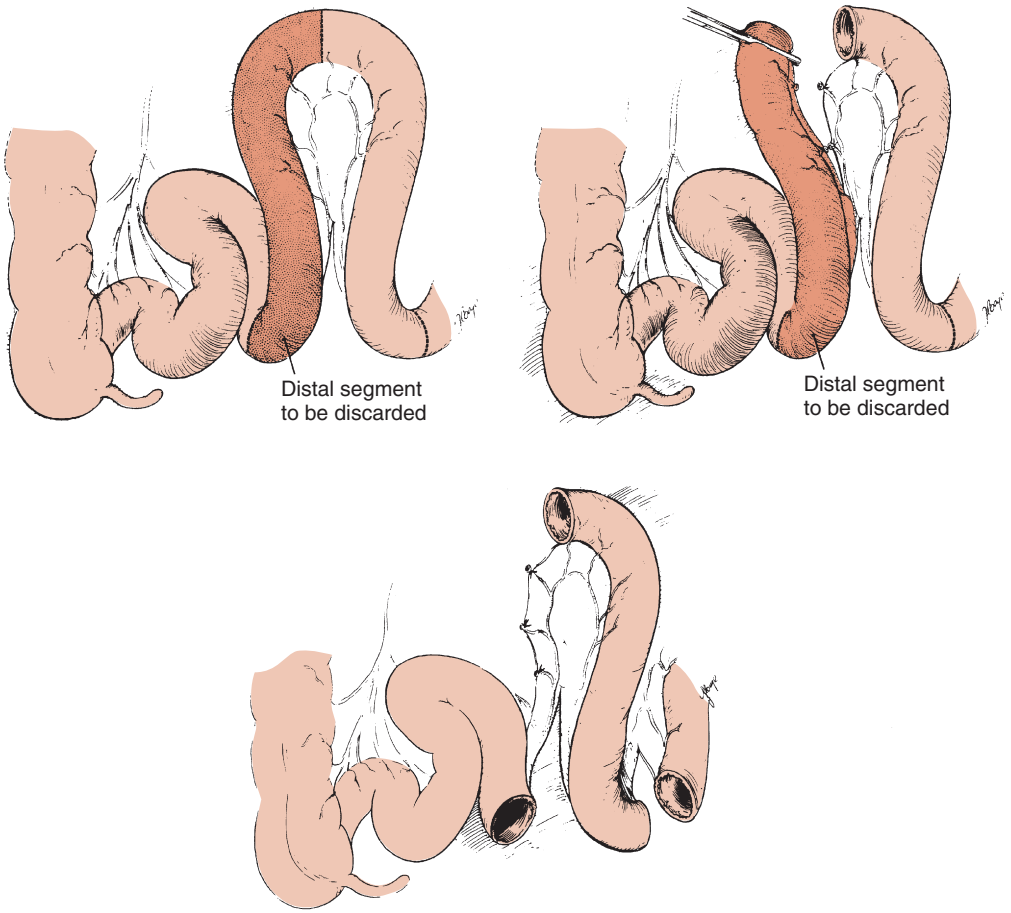


Figure 45.1 Daniel's technique of discarding the distal half of the loop in creating an isolated segment. (From Ehrlich R. Ileal conduit. J Urol. 1973;109:994.)

The position of the stoma should be marked preoperatively to ensure adequate fit of the stomal appliance and ease of stomal care on the part of the patient.

Marking of the stomal site should be done with the patient lying down, sitting, and standing, with an attempt to find a flat area on the abdomen. A permanent marking pen or subcutaneous puncture with a needle can be used to mark the planned stoma site preoperatively. Care must be taken to avoid the belt line, abnormal skin creases, and deformities such as scars, bony prominences, valleys, or ridges. Patients should be given the option of wearing a simulation stoma preoperatively, and the surgeon should evaluate the patient carefully to ensure adequate manual dexterity. The stoma should be within the rectus muscle, generally below the umbilicus, on top of the infraumbilical fat mound, and it should be well within the patient's visual field (Fig. 45.2).[25]

On rare occasions, a supraumbilical site should be chosen to avoid a protuberant abdomen. This allows the patient to see the stoma clearly and to change the stoma appliance. If such a site is chosen, the conduit is generally brought completely into a retroperitoneal location behind the right colon. The mesentery of the isolated segment can be placed in a retrocolic position or brought through the right mesocolon to place the conduit in the right paracolic gutter. Alternatively, a transverse colon conduit can be used.

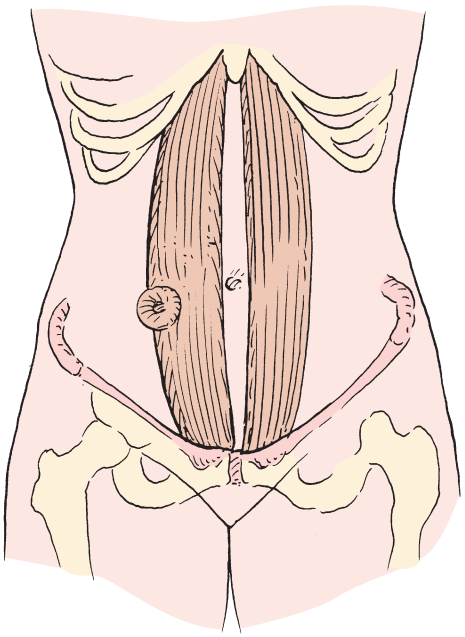


Figure 45.2 Stomal placement. Ample margins from adjacent protuberances and deformities are imperative.

Before entering the operating room, the patient must be adequately prepared for the future conduit and its care. The advent of stomal therapists in the 1950s greatly reduced the incidence of stomal complications and permanent defects.[4] When evaluating whether preoperative teaching and marking had any benefit, Bass and colleagues[26] found that those patients who received preoperative teaching had fewer total stomal complications (32.5%) compared with patients who had no preoperative teaching (43.5%). Thus, we strongly encourage that all preoperative teaching and stomal marking be performed by an enterostomal therapist.

EXTRACORPOREAL VERSUS INTRACORPOREAL LAPAROSCOPIC URINARY DIVERSION

With the expansion in use of robotic laparoscopic techniques, many surgeons are choosing to perform radical cystectomy robotically, a practice that consensus guidelines have deemed a reasonable alternative to open radical cystectomy.[27] Early robotic-assisted radical cystectomy (RARC), as described by Menon and colleagues,[28] utilized extracorporeal techniques for construction of the urinary diversion, primarily as a way to limit operative time. Initial studies evaluating the safety and efficacy of intracorporeal urinary diversion (ICUD) showed high rates of complications associated with ICUD relative to extracorporeal urinary diversion (ECUD),[29] largely attributed to the learning curve, which led many surgeons to continue using extracorporeal techniques.

Subsequent investigations into use of intracorporeal techniques for the construction of urinary diversions have been more promising. Ahmed and colleagues from the International Robotic Cystectomy Consortium (IRRC)[30] studied 167 patients who had undergone ICUD, 106 of whom were given an ileal conduit. Compared with a group of 768 patients who had undergone ECUD, patients undergoing ICUD had comparable operative times. The authors also found that patients who had undergone ICUD had significantly fewer postoperative complications at 90 days and also significantly fewer postoperative gastrointestinal complications, such as ileus. They also noted a lower rate of readmission at 30 and 90 days, but acknowledged, however, that there was likely a selection bias for patients in the ICUD arm of the study.

Koupparis and colleagues[31] were able to replicate these encouraging findings in their own patient cohort. Their study demonstrated lower complication rates for patients with ICUD than for those with ECUD (31% vs 48%). They also evaluated recovery times from the procedures, finding that patients with ICUD had significantly shorter hospital stays than those who underwent ECUD (8 vs 13 days). The length of stay in this case may reflect geographic variation in hospitalization practices. In our experience, uncomplicated open cystectomy and ECUD results in a typical hospitalization of 4–6 days, with an occasional range of up to 10 days among patients experiencing significant ileus. Whether reductions of length of stay can truly be achieved with ICUD remains controversial and is likely heavily influenced by regional variations in surgical approach, experience, and care pathways.

With possible advantages to ICUD, particularly in terms of length of hospital stay, fluid loss, and complication rates, the matter of the learning curve becomes quite important for surgeons considering use of the technique. Desai and colleagues[32] conducted ICUD on 37 patients and evaluated and found a significant decrease in console time between the first nine and last 10 cases in which the procedure was performed. Others[33,34] have reported the learning curve for intracorporeal techniques to be 30 cases.

Ultimately, many questions remain about the benefits and safety of ICUD. While recent studies have yielded encouraging results, prospective trials will be useful toward determining whether ICUD or ECUD will yield the more favorable postoperative complication profile. Ultimately, it may be difficult to separate the effects of laparoscopic cystectomy from ICUD in evaluating length of stay and complication rate, with the exception of evaluating those complications specific to the diversion.

Complications

CONDUIT

Necrosis of the conduit is a rare but disastrous complication. It invariably results from acute ischemia of the conduit, usually secondary to mesenteric injury, twisting, or an inadequately identified blood supply. In the early postoperative period, it is not unusual for the stoma to appear dusky. This discoloration is often caused by venous congestion arising from compression of the segment by local edema above the fascial opening. Within a few days, this phenomenon usually resolves. Drainage is maintained by use of a red rubber catheter inserted beyond the level of the fascia and brought out through the stoma. The red rubber catheter can usually be removed 48 hours postoperatively.

When selecting a bowel segment, the surgeon should identify a clear arterial supply that will be preserved following mesenteric division. This should be separate from the ileocecal artery to maintain blood supply to the bowel anastomosis. The mesentery should be handled carefully, and while the conduit is positioned, no twist or stretch of the mesentery should be present. In closing the mesenteric defect above the conduit, the surgeon should avoid laceration or incorporation of the arteries within the conduit mesentery.

Acute necrosis of the conduit usually manifests with a dusky, oozing stoma and may be accompanied by metabolic acidosis, hyperphosphatemia, or early shock. Alternatively, the patient may not be ill, but the dusky appearance of the stoma may persist for several days postoperatively. In cases of severe acidosis despite a normal-appearing stoma, one should consider a subfascial segmental infarct of the conduit, which can occur on rare occasions. The usual course of action consists of early exploration with resection and replacement of the conduit or diseased segment. Chronic ischemia of the conduit can occur and usually results in a rigid, poorly compliant conduit or stomal stenosis. Chronic ischemia may manifest with upper urinary tract dilatation resulting from poor drainage of the conduit. In this case, surgical intervention with repeat diversion is usually indicated.

Calculi

The incidence of calculi formation in patients with ileal conduits is 5–20%.[35–37] These calculi are usually renal in

origin, but stones can also form within the conduit itself. Of note, Gilbert and colleagues[38] found a lower incidence of urolithiasis among patients who received a conduit urinary diversion relative to those with continent urinary diversion. The proposed mechanism of stone formation involves a combination of urinary stasis, contact with bowel, and infection, and reduced urinary stasis could help explain Gilbert and associates' findings. Delayed or incomplete emptying of the conduit allows for longer contact times between urine and the intestinal mucus. This situation results in enhanced and increased chloride and bicarbonate exchange, with subsequent metabolic acidosis. Hypercalciuria develops as the bone-buffering mechanisms try to correct the acidosis. When hypercalciuria occurs in the presence of alkaline urine, stone formation is favored. Additionally, infections with urea-splitting organisms release ammonia and may facilitate chloride-bicarbonate exchange and further stone formation.[37,39] Prevention of calculus formation is usually directed at serum alkalinization with bicarbonate (Sholh's solution) or potassium citrate (Urocit-K), prevention of residual urine (catheterization as needed), prevention of infection with urea-splitting organisms (antibiotics), urinary acidification agents (vitamin C), and thiazides to enhance proximal tubular calcium reabsorption.

In addition, stones have been reported to form from retained staples or nonabsorbable sutures. Thus, the surgeon should make an effort to exclude or excise all staples from the bowel lumen during construction of the conduit. The distal staple line of the resected bowel should be completely excised, and the proximal staple line can be excised or excluded from the lumen using Parker-Kerr sutures (a running horizontal mattress stitch) of 2-0 polyglactin 910 (Vicryl). On rare occasions, a staple may erode into the conduit lumen and may cause stone formation.

Upper tract calculi may be treated with extracorporeal shock wave lithotripsy, percutaneous nephrolithotomy, or retrograde techniques, if access is possible. Extracorporeal shock wave lithotripsy may be difficult to perform because these stones are usually infectious, large, and difficult to clear. Cohen and Streem,[40] however, reported a 95% success rate with extracorporeal shock wave lithotripsy (occasionally, second therapy was needed). Percutaneous nephrolithotomy has a success rate of 100% and is the method of choice for large renal calculi.

Calculi that develop within the conduit may be treated with endoscopic techniques employing laser lithotripsy. Access can be obtained with a flexible cystoscope or, in larger conduits, with pediatric endoscopes. Stones arising from an exposed staple or staple line should be broken prior to the attempt to extract, in order to avoid perforation of the adherent bowel wall. The causal factors in conduit stone formation must also be investigated, and any staples should be removed endoscopically if they are identified.

Malignant Disease

Carcinoma within the conduit has been reported since the development of urinary diversions. The first case of ureterosigmoidostomy-associated cancer was reported in 1929, and the incidence of cancer following ureterosigmoidostomy has been reported to range between 6% and 29%.[41] In fact, the risk of developing adenocarcinoma after ureterosigmoidostomy is 400 to 7000 times that of the general population. Husmann and Spence[41] found that 26 years after diversion, 70% of patients had developed adenocarcinoma. However, the rate of carcinoma developing within colon and ileal conduits is <1%.[42] Since 1950, four cases of adenocarcinoma developing in an ileal conduit have been reported.[43,44] The rarity of these cases is likely, in part, the result of the infrequency of primary small bowel tumors.

The origin of adenocarcinoma in bowel conduits is unclear. Gittes[45] found that carcinogenesis of ureterosigmoidostomy depended on the presence of urine, feces, urothelium, and a healing anastomotic suture line. He assumed that the use of bowel segments interposed into the urinary tract would not lead to tumor formation in the absence of feces. This theory has since been challenged. Other hypotheses include chromosomal abnormalities, *N*-nitrosamines, oxygen free radicals, infection, and chronic inflammation. Malignant transformation in these cases may also be an early event.[42]

Three cases of carcinoid tumor arising in an ileal conduit have also been described in the literature.[46,47] Transitional cell carcinoma developing in the conduit has been reported as early as 9 months postoperatively. Mulholland and coworkers[48] reported finding grade 2 transitional cell carcinoma arising from the bowel mucosa at a site completely separate from the ureter. In any patient undergoing creation of an ileal conduit, the upper urinary tracts must also be followed as well because of the 2–9% rate of upper urinary tract transitional cell carcinoma following cystectomy.[49]

BOWEL

Bowel complications occurring after conduit surgery are generally related to the ileal resection and anastomosis. When constructing an ileal conduit, the surgeon selects a segment approximately 10–15 cm proximal to the ileocecal valve. Despite preservation of the terminal ileum, malabsorptive syndromes can arise, particularly if long segments of bowel are resected. Diarrhea in the early postoperative period is often the result of prolonged antibiotic use and bile salt malabsorption. This complication generally improves spontaneously in ≤4–6 weeks. The patient should be encouraged to drink fluids liberally and should avoid the use of motility-suppressing agents. A culture for *Clostridium difficile* should be obtained. In rare cases of severe or persistent diarrhea, oral cholestyramine can be used to form bulk and decrease transit time.

Vitamin B_{12} deficiency can arise from poor absorption following ileal resection. Levels should be monitored periodically starting 6–12 months postoperatively. Individuals developing anemia at prolonged intervals following surgery should be evaluated for vitamin B_{12} deficiency.

Anastomotic leak, bowel obstruction, and ileus are common problems following ileal diversion and are discussed in detail in Chapter 11. Early recognition is paramount in avoiding the necessity for bowel resecting or ileostomy.

STOMA

Construction of the stoma is perhaps the most critical aspect of conduit surgery because the stoma is the most

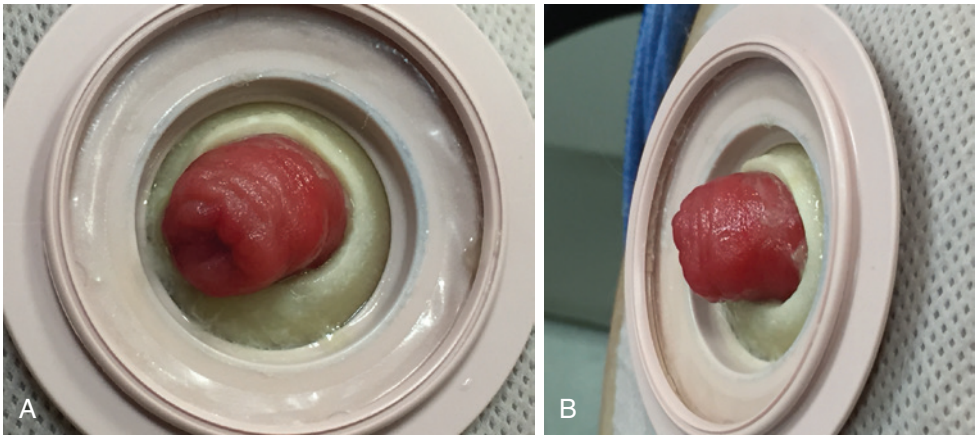


Figure 45.3 Properly constructed ileal stoma with (A) good appliance fit. B, The stoma protrudes approximately 1.5–2.0 cm from the abdominal wall, allowing proper fit of the stomal appliance. Less than 1/8 inch of skin is exposed circumferentially. The stoma protrudes into the appliance.

likely site of complication. In addition, the stoma greatly influences the patient's quality of life. Preparation of the stoma site, transposition of the bowel segment through the abdominal wall, and maturation of the stoma should be carried out with great caution and meticulous attention to detail. In patients in whom a conduit will undoubtedly be constructed, preparation of the stoma site can be carried out before the midline incision is made. This technique allows the surgeon to align the abdominal musculature in anatomic position with the skin opening, to use the preoperatively marked stoma site without confusion, and to be fresh and alert at the time of site preparation.

Regardless of surgical technique, the essential points of stomal preparation include an abdominal wall opening that can accommodate the conduit without ischemia but is snug enough to provide support, passage through the rectus sheath to avoid herniation next to the stomal opening, and adequate protuberance and maturation of the stoma to ensure good fit of the appliance (Fig. 45.3) Although a comprehensive discussion of technique is beyond the scope of this chapter, those points critical in preventing complication are discussed.

Early complications relevant to the stoma are generally related to poor vascularity, as discussed earlier. Delayed or late complications of the stoma are common, and these include parastomal hernia and prolapse, stomal retraction, local dermatitis, and stomal stenosis. As a result, stomal complication is the most common cause of reoperation after conduit surgery. In Bricker's[50,51] evaluation of the complications of 543 ileal conduits, stomal complications were responsible for reoperation 26% of the time. Cass and associates[52] found that 57% of all reoperations were for stomal problems. Klein and colleagues[53] from the Cleveland (Ohio) Clinic reported their results and noted a 5% overall stomal revision rate. These investigators also found no difference in the complication rates when they compared end stomas with loop stomas.

Cheung[54] analyzed 322 stomas, of which 123 were ileal conduits. The overall complication rate from the stoma alone was >60%, and transverse colostomy had the highest rate of complications at 73%. The overall rate of stomal complications with ileal conduits was 62.6%. With an average 6 years of follow-up, Cheung identified stenosis in 7.3%, parastomal hernia in 27.6%, prolapse in 4.1%, and excoriation in 20.3% of his patients. The average time to stenosis was 128 months, whereas the average time to herniation was 22 months; 23% of all stomal hernias occurred within the first year.[54]

Parastomal Hernia or Prolapse

The reported incidence of clinically evident parastomal hernia ranges from 4.5% to 13.9%[55] for ileal conduit surgery, although the rate of radiographically diagnosed parastomal hernia has been reported to be as high as 50% 2 years postoperatively.[56] Potential contributing factors include obesity, wound infection, chronic cough, steroids, malnutrition, and abdominal distention. Most patients are asymptomatic, but 10–20% may have symptoms, including pain, poor-fitting appliances, poor cosmesis, and potential bowel strangulation.[57] Early studies indicated a higher rate of parastomal hernia in patients receiving an end ileostomy rather than a loop ileostomy. Subsequent analyses have shown similar rates of parastomal hernia between the two methods.[53,56]

Parastomal hernias arise when a gap exists between the intestinal segment forming the stoma and the surrounding tissue.[58] The fascial defect may be created by tangential forces working on the circumference of the opening that can stretch the fascia.[57] Most commonly, incorrect placement of the stomal opening lateral to the rectus fascia results in gradual opening of the surrounding fascia. Sjodahl and colleagues[58] evaluated 130 patients with intestinal stomas and found the incidence of parastomal hernia to be 2.8% in patients with stomas brought through the rectus muscles compared with 21.6% in patients whose stomas were placed lateral to the rectus muscles. In the operating room, the surgeon should note that the entire fascial opening is within the body of the rectus sheath. Creating the fascial opening before making the midline incision can assure the surgeon that all fascial layers are aligned. Placement of reinforcing sutures between the bowel serosa and the posterior layer of the abdominal fascia can be considered (in either interrupted or continuous fashion), but it is unclear if this reduces stomal hernia incidence. If done, care should be exerted to ensure no kinking or obstruction of the conduit lumen occurs, and that the placement of

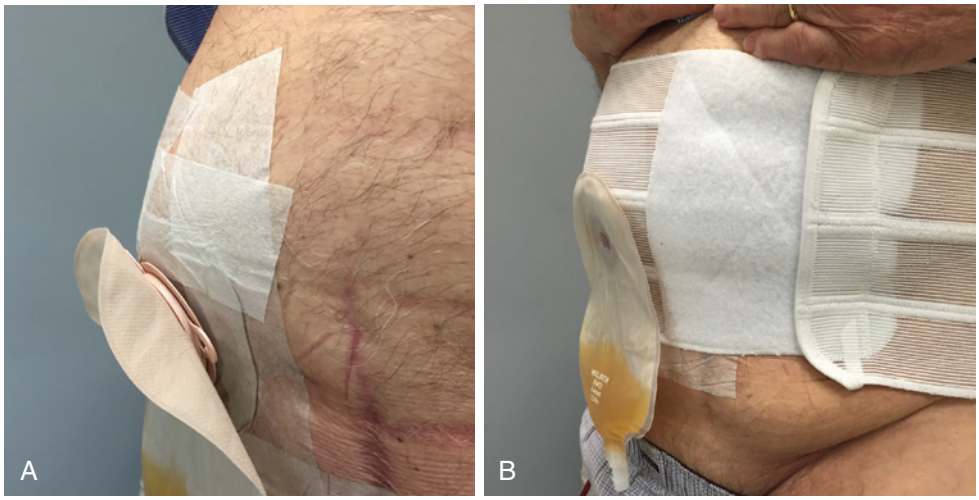


Figure 45.4 A patient with a largely asymptomatic parastomal hernia (A), which is not resulting in any stomal retraction or difficulty with appliance, and no proximal obstruction or pain. (B), A stomal belt and abdominal binder can aid in preventing progession of the hernia and discomfort during activity.

sutures in the posterior fascia does not cause stomal retraction at the skin level. In general, if such sutures are to be placed, they should be placed 3–4 cm proximal to the stomal maturation.

Repair of parastomal hernias can be difficult and should be attempted only if the patient is symptomatic. Conservative options include support belts or appliances to keep the hernia reduced and appliances that eliminate the need to repair the hernia operatively (Fig. 45.4). Surgical options can become complicated and include relocating the stoma to a new site or repairing the fascial defect, either primarily or with the use of synthetic material. The surgeon should realize, however, that untreated parastomal hernias usually worsen, and earlier repair may be technically easier.

Rubin and associates[59] reported on 94 parastomal hernias repaired surgically. These investigators found a 76% incidence of recurrence after fascial repair compared with a 33% incidence after stomal relocation. For patients with recurrent parastomal hernias, fascial repair with synthetic material had the lowest recurrence rates (33%). Overall, 72% of patients developed additional abdominal hernias at the old stoma site, recurrent parastomal hernias, or herniation at the laparotomy incision site. The morbidity associated with surgery was also high; 63% of patients had at least one postoperative complication. These investigators concluded that parastomal hernia is rarely life threatening, and repair should be avoided if possible because of poor success rates and high rates of morbidity and recurrence.

In another approach to repairing parastomal hernias, reported by Kaufman,[60] the stoma is relocated without a laparotomy incision. The stoma is dissected off the skin and is dissected to its base. Any adhesions are freed. A cruciate incision is made on the patient's contralateral side, and the stoma is delivered to this new site with the use of long sponge forceps and dissection from the herniated side. Such an approach is somewhat blind, and the surgeon should exercise caution in selecting patients with minimal intra-abdominal reaction or adhesion.

A technique described by Leslie[61,62] uses a suprafascial synthetic wrap to close the hernia defect. A skin flap is elevated from medially to laterally to expose the underlying fascia for 10–15 cm circumferentially around the stoma. The stomal skin is left intact. The fascial defect is exposed, the peritoneum is opened, and the conduit and fascial edge are freed from all intraperitoneal contents. The fascial defect is then closed directly or with interposed absorbable mesh. Once the fascia is closed, nonabsorbable mesh is wrapped around the bowel segment and is tacked only to the fascia, approximately 8–10 cm away from the conduit. Slight overlap of the edges allows the protuberance of the stoma to be retained by gathering up the bowel centrally. The synthetic material used should be chosen carefully and should not be tacked to the bowel because it has the potential to erode into the conduit over time. Gore-Tex appears to be the material of choice.

The role of prophylactic mesh to reduce the incidence of parastomal hernia is a relatively new field of investigation with promising early data, primarily from the general surgery literature.[63–66] Investigations into its applications in the context of conduit urinary diversion are limited. Styrke and colleagues[67] conducted a 10-year case study in which they placed mesh anterior to the peritoneum, not anchored by sutures, in 114 consecutive patients receiving ileal conduits. Parastomal hernias were noted in 14% of patients at mean follow-up of 35 months, with no mesh-related complications in any of the patients. Donahue and colleagues[68] offered prophylactic mesh to 40 patients with a BMI >30, finding a radiographic parastomal hernia rate of 18%, but a clinically apparent parastomal hernia in one patient and no mesh-related complications. Prospective studies, which are currently underway, are necessary to determine whether prophylactic mesh is safe and effective and stratify the patients for whom it is most appropriately used.

In considering use of therapeutic or prophylactic mesh placement, caution should be exerted to avoid direct contact of the mesh edge with bowel serosa. A concern remains, in our view, for mesh erosion into the conduit lumen over time, and long-term follow-up of the previously discussed studies is critical before widespread adaptation of the approach.

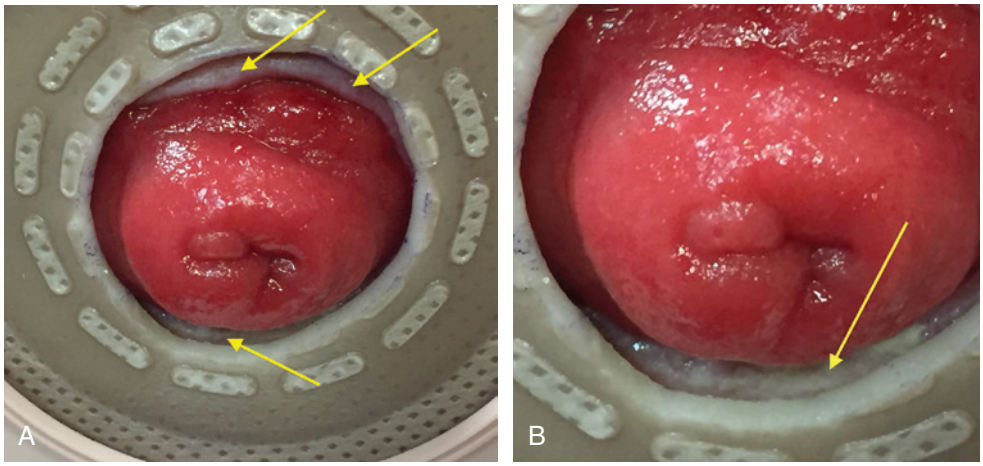


Figure 45.5 A poorly fitting stomal appliance, either due to improper preparation of the wafer or flattening of the stoma, results in (A) exposure of the surrounding skin (yellow arrow) to urine pooling and, ultimately, (B) hyperkeratotic changes (yellow arrow). These changes precede eventual stomal stenosis.

Stomal Stenosis

Stomal stenosis has a reported incidence of from 0.7%[55] to 19%. Frazier and associates[69] reported on 675 cases performed at Duke University (in North Carolina) in the 1970s and 1980s. These investigators found a 2.8% incidence of stomal stenosis. Factors contributing to the development of stomal stenosis include fascial or muscular constriction, ischemia of the stoma, shape and retraction of the stoma, alkaline urine, hyperkeratosis, and local skin changes.

The most common pathophysiologic features of stomal stenosis usually start soon after the surgical procedure. Poorly fitting appliances, often the result of stomal retraction, can cause skin ulceration and irritation that can eventually lead to hyperkeratosis of the local skin (Fig. 45.5). This complication ultimately results in stenosis (Fig. 45.6). Additionally, leaking of the stoma underneath the appliance can cause local skin irritation (Fig. 45.7A) and superficial excoriation (Fig. 45.7B).

Alternatively, stenosis can occur at the level of the fascia in response to an inadequate opening, which over time may result in kinking of the conduit. Abdominal wall muscular spasm in patients with neurologic disease can cause a similar situation. This complication usually responds to antispasmodic medications. When stomal stenosis exists, it can start a cascade of events leading to obstruction, dilatation with reflux, urinary tract infection, sepsis, and renal damage.

When fashioning the stoma, the surgeon must assess for adequate blood supply and adequate mucosal nipple above the skin to guarantee proper fitting of the appliance. The matured stoma should extend 1–2 inches above the skin edge for proper appliance fit. If the stoma is too long, this can impair drainage within the bag. Appliances should be no more than 1/16 to 1/8 inch larger than the stoma to minimize urine contact with the skin. Proper maturation of the stoma and selection of the appropriate site for stomal placement are the most critical factors in determining the success of the stoma.

The presence of a bulky mesentery can prevent proper maturation of the stoma. Placement of maturing sutures in positions directly next to the mesenteric edge can allow the



Figure 45.6 Terminal stomal stenosis (arrow).

distal bowel edge to fold over the mesentery. Ligation of ≤5 cm of the distal mesentery to prevent bowing of the stoma has been advocated by some investigators, but it does have the increased risk of stomal devascularization and associated problems and is not usually necessary. *Defatting,* or removal of excess lateral fat from the edge of the mesentery, can be performed by gently teasing away the fat along the bowel wall. Care must be taken to avoid laceration of the mesenteric vessels that lie centrally within the mesenteric fat. The tendency to tuck excess mesentery beneath the skin edge should be avoided because it creates a large mound next to the stoma and causes difficulty with the fit of the appliance.

Anchoring the conduit to the rectus fascia to prevent stomal retraction is controversial. In general, if no tension is present on the intraabdominal portion of the conduit, no retraction should occur. Obesity and postoperative distention can obviously affect this situation. We place two to three sutures from the edge of the anterior rectus fascia opening to the seromuscular layer of the conduit as it passes

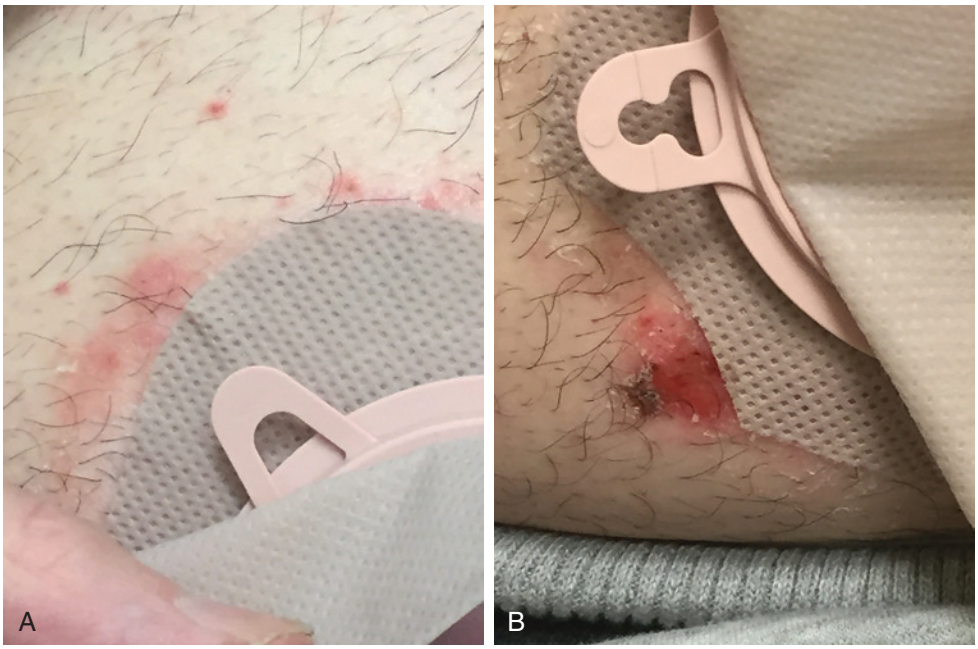


Figure 45.7 Leakage of urine beneath the stomal appliance can lead to local skin irritation: (A), superficial skin irritation, and (B), excoriation.

through the fascia. Additional sutures can also be placed in the posterior rectus sheath. These stitches should not be under traction or they may risk bowel wall ischemia.

We reported a modified technique of stomal maturation before abdominal wall transposition of the conduit or stoma.[70] We observed that this modification allows more symmetric eversion, tension-free anastomosis, and less likelihood of stomal retraction. Since the initial report in 2009, we have institutionally adhered to the "Taneja technique" of stomal maturation. The technique is begun by defatting the distal 4 cm of mesentery to allow circumferential eversion of the stoma using four seromuscular sutures (Figs. 45.8 and 45.9). The bowel intussusception is locked in place with through-and-through sutures from the lumen to the external stomal surface, and the mesentery is then tucked under the everted bowel edge to ensure that no retraction of the stoma occurs along the axis of the mesentery (Fig. 45.10A). Finally, the matured edge of the intussusception is anchored to the dermis circumferentially while sutures from the fascial edge are placed to the seromuscular layer 2–3 cm proximal to the matured edge of the stoma to prevent retraction (Fig. 45.10).

Hyperkeratosis is characterized by thickening and hardening of the skin and proliferation of the epithelium. This complication can be treated with catheter drainage to avoid urinary contact with the skin, in combination with the application of a heat lamp 12 inches from the skin twice daily. External beam radiation therapy has also been reported to be beneficial in severe cases of hyperkeratosis.[48,71] Bacterial and fungal infections can initiate stomal deterioration. Continued exposure to alkaline urine can cause stomal encrustation, stomal epithelialization, and eventual stomal stenosis.[25,72] Treatment options include 500 mg of vitamin C four times a day or 0.25% acetic acid washes twice a day. Early local skin care accompanied by urinary acidification is essential to prevent progression of the problem and can often reverse it. If combined with significant stomal retraction, early revision with excision of the hyperkeratotic skin may be advisable.

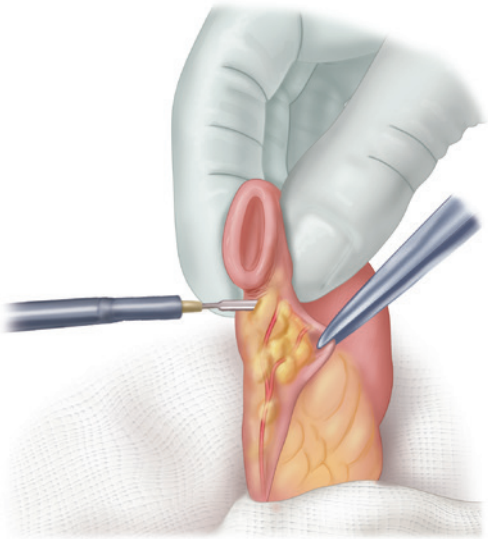


Figure 45.8 The Taneja technique of stomal maturation. Technique of mesenteric defatting. The thickness of the mesentery is reduced by excising excess fat, but the central vascular arcades are preserved.

The techniques for surgical revision of a stenotic or retracted stoma are many. In general, repair can be performed locally through a circumscribing incision at the stoma site (Fig. 45.11). The conduit wall is identified in the subdermal tissues, and the conduit is then freed completely to the level of the fascia. Great care should be exercised in avoiding the mesentery of the bowel. The fascia is freed from the conduit wall, and the bowel is then mobilized intraperitoneally. Extensive conduit length can be achieved in this fashion. The distal stenotic segment of the stoma is then excised along with hyperkeratotic local skin, and rematuration of the stoma is performed (Fig. 45.12). To

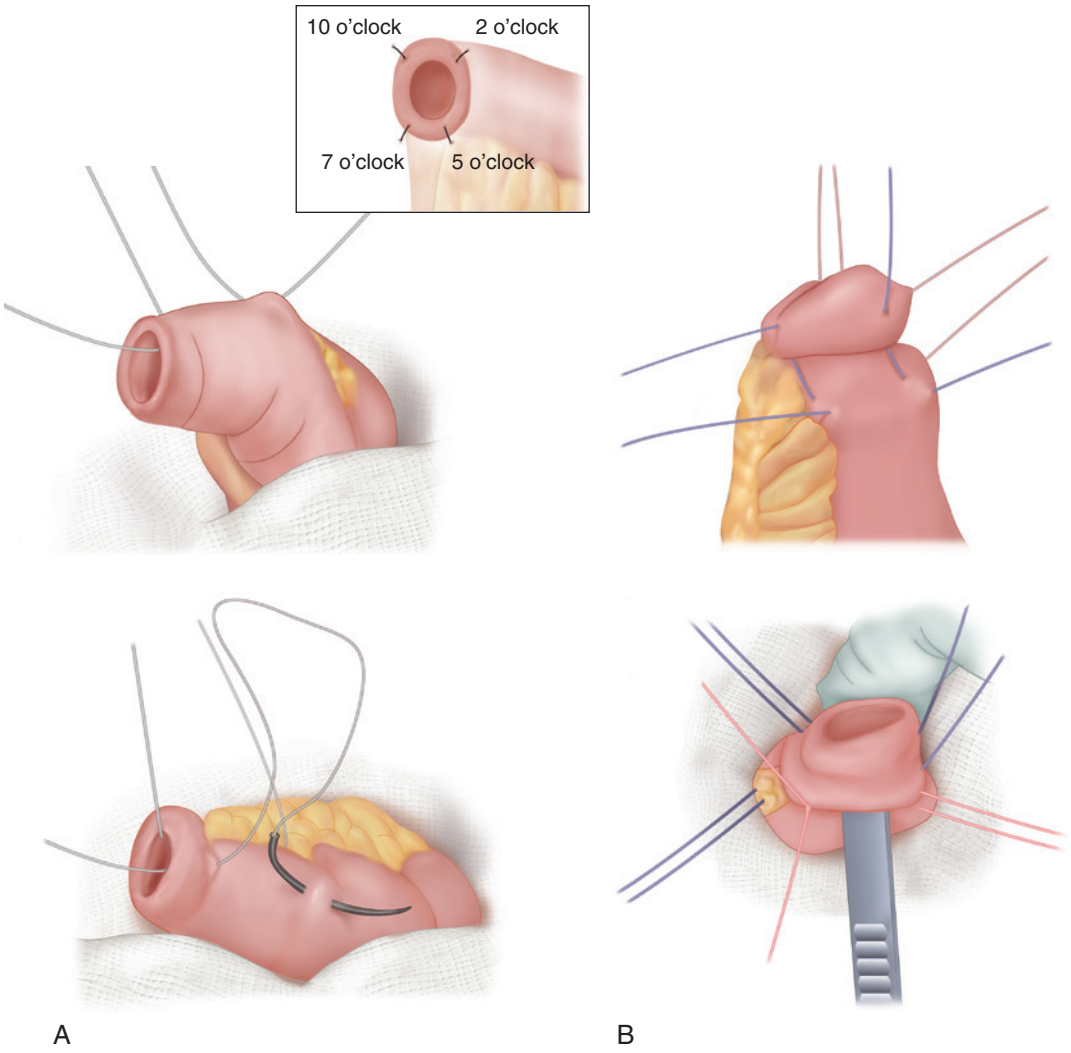


Figure 45.9 The Taneja technique of stomal maturation. A, Creation of stoma by mucosal eversion and distal bowel intussusception. Sutures are placed from the cut bowel edge to the seromuscular layer approximately 4 cm proximal to the edge. B, If one considers the mesenteric position at 6 o'clock, the everting sutures are placed at 2, 5, 7, and 10 o'clock to maximize eversion to the mesenteric edge and to avoid the necessity for suture placement in the mesentery.

facilitate intraperitoneal mobilization, the fascial opening can be extended, but careful closure must then be performed to avoid subsequent herniation.

Alternative techniques of dealing with an incomplete stenosis involve incision of the stenotic ring with either direct reanastomosis to the skin or rotation of a secondary skin flap into the defect (Figs. 45.13 and 45.14). The shortcoming of these techniques is that they do not address the problem of stomal retraction. On rare occasions, full laparotomy is required to achieve adequate conduit length for stomal maturation. A preoperative loopogram can provide critical information in determining the intraperitoneal availability of redundant conduit.

URETEROINTESTINAL ANASTOMOSIS

During mobilization of the ureter, preservation of the periureteral adventitia is essential to ensure adequate blood supply to the ureter. Before creating the anastomosis, the surgeon must ascertain adequate length from each ureter. In addition, when placing the stoma on the right, the surgeon must pass the left ureter beneath the sigmoid mesocolon with gentle angulation and must be careful to avoid kinking the ureter. These are the basic tenets of constructing the ureterointestinal anastomosis.

Numerous anastomotic techniques exist, and to a large extent, the segment of bowel used, the dilatation of the ureters, and the preference of the surgeon are the deciding factors. Bricker's[2] initial description of the ureteroileal anastomosis employed an end-to-side (ureter-to-bowel) approach with wide spatulation of the ureter. Wallace[73] subsequently reported an end-to-end anastomosis in which the two ureters were converted to a single lumen and were anastomosed to the proximal end of the bowel. Creation of an adequately sized well-vascularized lumen, mucosa-to-mucosa apposition with watertight closure, and sufficient mobilization of the ureter to reduce tension on the anastomosis are necessary. Ultimately, the comfort of the surgeon with an individual technique is likely the greatest predictor of success.

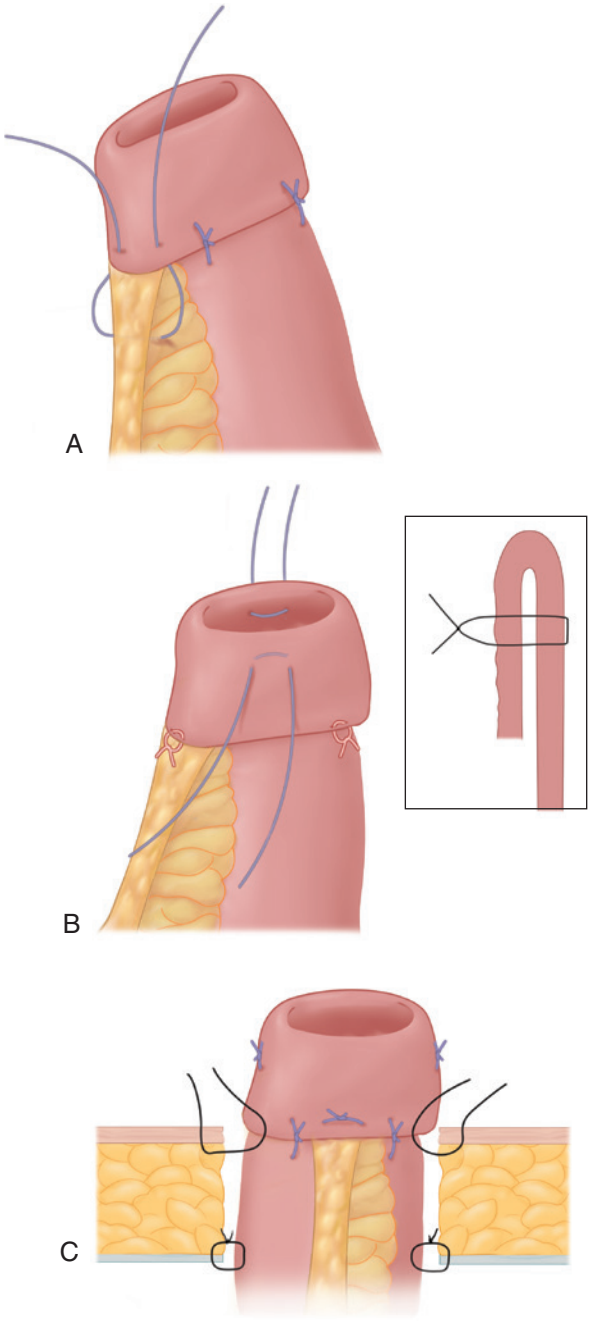


Figure 45.10 A and B, The Taneja technique of stomal maturation. Eversion over the mesentery is performed by suturing to the mesenteric edge with a U-stitch (inset in B). The stomal intussusception is held in place with through-and-through sutures from the lumen to the exterior surface. C, On abdominal wall translocation, the stomal edge is anastomosed to the skin and fascial sutures are placed approximately 3 cm proximal to the everted stomal edge.

Various techniques for ureterocolonic anastomosis have been described. The technique most commonly used for conduit diversion, however, is antirefluxing tenial anastomosis. As discussed later, the necessity for antirefluxing anastomoses remains to be validated in this setting. The use of a stent in the ureteroileal anastomosis is a subject of great controversy. We routinely use a stent for the following reasons:

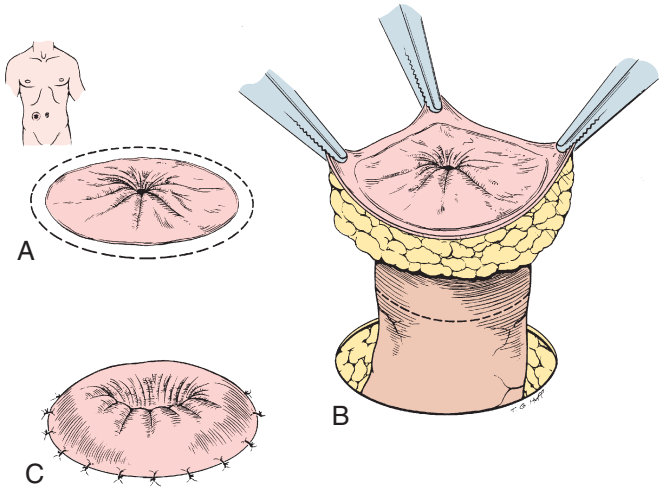


Figure 45.11 Reconstruction with distal amputation. A, Circumferential incision is made around the stoma. B, Mobilization of stoma and distal conduit and amputation of distal segment are performed. C, New stoma is fashioned.

1. It ensures the patency of the anastomosis, specifically in the immediate postoperative period when edema is present at the site.
2. It provides access to the kidney and collecting system if retrograde studies are needed.
3. It enhances stomal drainage when long, externally draining stents are used.

Numerous urinary diversion stents can be used, including a single-J stent or a double J stent with external extension. We prefer the double J variety because it ensures some urine in the conduit and thus prevents a completely dry anastomosis in the early postoperative period.

Regan and Barrett[74] compared the incidence of stricture and leakage in stented and unstented anastomoses. Those patients who were stented had lower rates of stricture and leakage compared with patients who did not have stents. This was a small study with relatively short follow-up, and the influence of technical factors and selection bias cannot be excluded. Individuals with stents in place may be at a high risk of ascending pyelonephritis and urosepsis in the postoperative period. For this reason, these patients should be administered antibiotic prophylaxis for the duration of stenting, and the stents should generally be removed by postoperative day 5–7. Although it is not clear that ureteral stenting is required for ureterointestinal anastomoses, it appears that the potential benefits far outweigh the potential harm.

Ureteroileal Anastomotic Leak

Ureteroileal anastomotic leak (extravasation) is reported to occur in 1.9–5.5% of conduits but alarmingly has an associated mortality rate of ≤48%.[75] The factors contributing to the occurrence of leakage include poor surgical technique, prior radiation therapy, recurrent cancer, stomal edema or obstruction, extraluminal hematoma or seroma, and pelvic abscess. During the normal postoperative course, a small amount of leakage from the anastomosis may occur, but this often resolves without any sequelae. Intraoperatively, the surgeon should make every effort to create a watertight

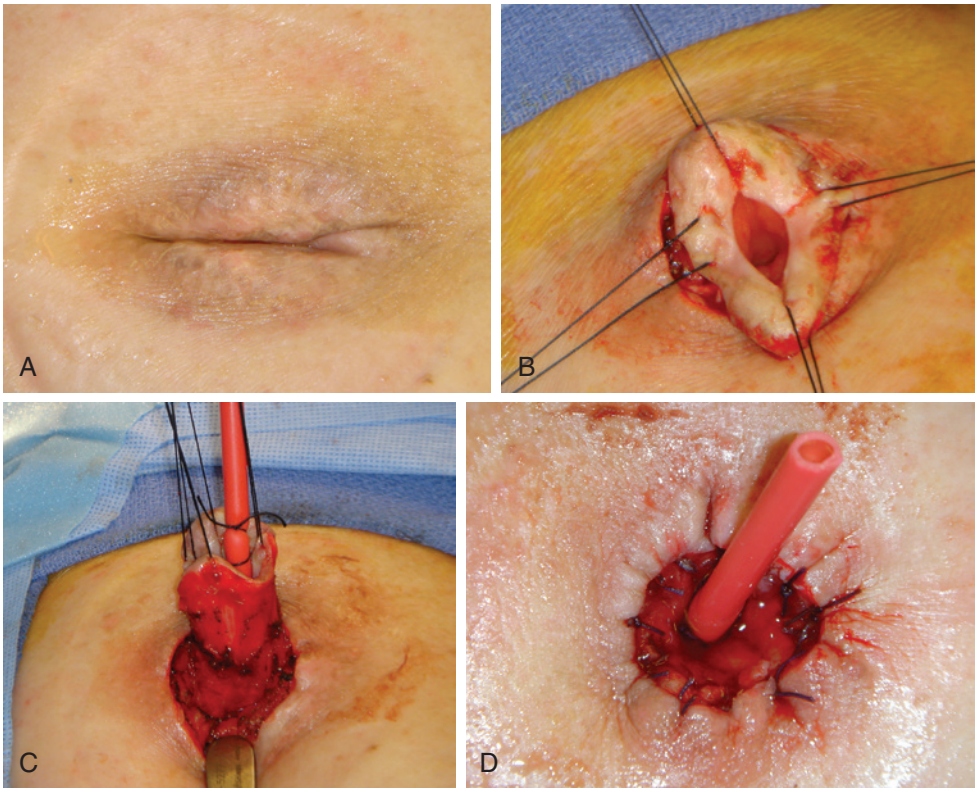


Figure 45.12 Demonstration of stomal revision. A, Completely stenotic stoma due to chronic retraction and inflammation. B, Excision of the stenotic ring by placement of stay sutures in the scar and elevation of the distal conduit. C, Lengthening of the conduit through mobilization beyond the rectus fascia. D, Maturation of stoma following excision of the stenotic ring and flush spatulation of the residual conduit.

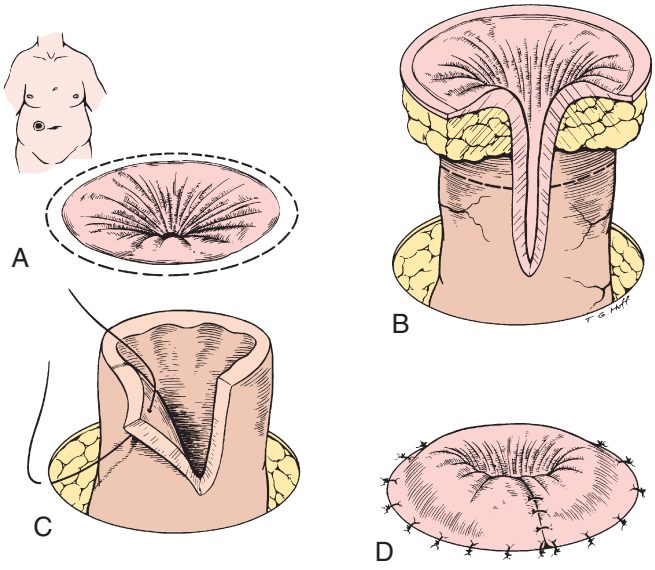


Figure 45.13 Reconstruction of a retracted stoma. A, Skin incision is made. B, The distal segment is amputated. C, Spatulation for a split-cuff stoma is made. D, Final stoma.

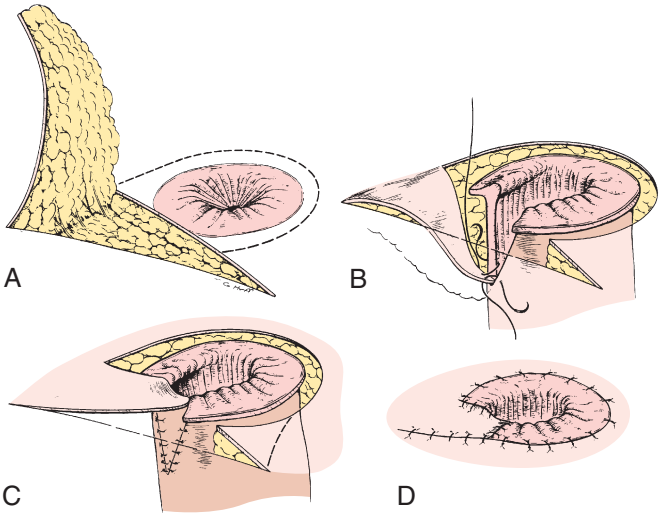


Figure 45.14 Skin inlay reconstruction. A, The old stoma and skin flap are mobilized. B, The stoma is spatulated. C, The skin flap is inlaid. D, The skin edges are reapproximated.

anastomosis so as to prevent a perianastomotic urinoma, which may become secondarily infected.

We routinely use a Bricker-type anastomosis in our conduit diversion procedures. During spatulation of the ureter, three directly juxtaposed 4-0 chromic anchoring sutures are placed at the apex, or corner, of the spatulation. Generally, this is the most dependent portion of the anastomosis and thus is the most likely to leak. Interrupted sutures are then placed circumferentially 3–4 mm apart. An indwelling stent is always used.

Significant urinary leakage should be suspected in the presence of increased drain output with decreased output from the stoma. Other signs and symptoms may include proximal hydronephrosis or flank pain if no stent is used,

sepsis, ileus, bowel obstruction, urinary drainage from the wound, elevated serum ammonia, or elevated blood urea nitrogen (BUN) without a concomitant elevation of the serum creatinine concentration. This last sign is the result of absorption of urine in the peritoneal cavity. Additionally, the creatinine level in the drainage fluid can also be measured. When the drainage fluid is urine, the creatinine level is generally markedly higher than is the serum creatinine. In a study of 1120 ileal conduits, Hensle and colleagues[76] found elevated BUN to be the most reliable indicator of a urine leak (20 of 21 patients).

Once concern of a leak exists, localization of the leak with a loopogram, intravenous pyelogram (IVP), computed tomography (CT) scan, cine loopogram with real-time fluoroscopy, or injection of contrast material into the ureteral stent can be helpful. CT loopogram may also help to localize the extent of leakage. The leakage commonly originates from the ureterointestinal anastomosis but can also originate from the middle or back of the loop. In our opinion, loopogram with real-time fluoroscopy is most helpful in defining the nature and severity of the leak. In the study by Hensle and colleagues,[76] left ureteral anastomosis was the most common site of leakage. One must also examine the stoma because edema may cause stomal obstruction with increased intraluminal pressure, increased back pressure, and eventual leakage.

When the diagnosis has been established, a conservative approach should be used initially. This approach includes ensuring of adequate drainage with a catheter in the stoma (on low suction if needed), drainage of the collecting system with either percutaneous nephrostomy tubes or ureteral stents, nutritional support, and antibiotic prophylaxis. Early leaks in the stented ureter can be observed initially, provided the patient has no signs of sepsis. Cross-sectional imaging should be used to rule out the presence of an undrained urine collection, which can compress or stretch the anastomosis and thus prevent its ultimate closure. High-output leaks in the presence of a stent should be managed initially by percutaneous drainage of the kidney to minimize urinary extravasation. In the absence of a ureteral stent, it is unlikely a major leak will seal without percutaneous drainage of the kidney and urinoma. Antegrade stenting is an option, but the surgeon should exercise extreme caution to avoid further disruption of the anastomosis.

Delayed leaks occurring >7–10 days postoperatively are often the result of ischemic ureteral necrosis. Early attempts at conservative therapy are still worthwhile, and percutaneous nephrostomy is an important adjunct to such therapy. If the leak continues as a high-output fistula despite proximal drainage, it may require early exploration because this finding suggests major ureteral necrosis. If proximal drainage reduces or abrogates fistula output, surgical repair is still likely necessary. However, waiting for 6–10 weeks to allow inflammation to subside is wise.

If the patient does not respond to conservative therapy, early surgical exploration and repair must be attempted. Hensle and colleagues[76] suggested repair after 72 hours if no improvement is noted, whereas Coleman and Libertino[77] suggested waiting ≤3 weeks. In the study by Coleman and Libertino, leaks in seven of 10 patients resolved after 3 weeks, whereas three of 10 patients required open revision. The decision to wait must be based on the patient's condition, the size of the leakage, the output volume, the presence of persistent infection, and the presence of signs of improvement.

In repairing an early leak, surgical exploration usually includes creating a new anastomosis. Simple placement of additional sutures in a preexisting anastomosis is rarely successful and is ill advised. Stent placement in the new anastomosis is strongly advised. The previous opening in the ileum should be identified and closed. To facilitate intraoperative dissection and mobilization, a Foley catheter with 3–5 mL in the balloon can be placed in the conduit. Antegrade stenting of the ureters is also helpful in localizing, mobilizing, and repairing the anastomosis.[77] The surgeon should anticipate very friable tissues, and the repair should focus on identification of a viable, minimally inflamed ureteral edge, mucosal apposition, and tension-free anastomosis. Watertight closure is often not possible because of the condition of the tissues. Eyre and associates[75] recommended sending the distal ureter for frozen section during repair, to assess tissue necrosis or small vessel occlusion. However, this condition may be difficult to assess in the presence of acute inflammation.

Patients with a delayed urine leak (10–14 days) usually have ischemic necrosis. This complication can involve a variable length of ureter and, in severe cases, can extend all the way to the renal pelvis. The technique of repair should be based on the length of the defect. Complete resection of the devitalized ureter must be performed with creation of an ileal interposition, transureteroureterostomy, or renal autotransplantation. Minimal-to-moderate gaps can be closed by mobilization of the proximal conduit itself. In patients with significant ureteral necrosis, critical illness or sepsis, or multiple comorbidities, the surgeon should give strong consideration to nephrectomy if the contralateral kidney is adequately functioning. Before surgical exploration, a renal scan may be performed to assess bilateral function, if necessary. Bowel preparation should be performed, if possible, based on the patient's overall condition.

Anastomotic Strictures

The incidence of ureteroileal strictures ranges from 1.5% to 18.4%.[35] For example, Bricker[50] found a 3.75% incidence of reoperation for ureteroileal obstruction in his initial 54 cases. In addition, Cass and colleagues[52] and Frazier and associates[69] reported stricture rates of 6.5% and 7%, respectively. Madersbacher and colleagues[78] noted upper urinary tract obstruction in 13 of 131 (10%) patients as a result of stenosis at the ureteroileal anastomosis, and Gburek and associates[79] reported a 5% rate of stricture in 66 patients, their most common late complication of ileal conduit creation. More recently, Gilbert and associates[38] noted a ureteroileal obstruction rate of 8% at 2 years, as well as an increased incidence among patients receiving a conduit diversion rather than a continent diversion. The possible causes of stricture formation include tension at the anastomosis, devascularization and ischemia of the ureter, prior radiation therapy, prior leakage, and infection. In the setting of prior leakage, dense reaction surrounding the ureteroileal reimplantation results in extrinsic scarring of the anastomosis. Stricture at the anastomosis should be considered in any patient with decreased renal function (increased serum BUN and creatinine levels), hydronephrosis, flank pain, decreased urine output, fever, or sepsis.

The diagnosis of ureteroileal anastomotic stricture can be made with ultrasound, CT scan, IVP, and loopogram. IVP and loopogram can localize and define the length of the stricture. Newer techniques, including three-dimensional reconstructed spiral CT scan, CT urogram, and magnetic resonance imaging urogram, may also be used if available. In patients with poorly functioning or nonfunctioning kidneys, antegrade pyelography is often necessary to define the stricture. Hudson and colleagues[80] reported a rate of correlation between loopogram and IVP of 81%. Although reflux on a loopogram can rule out stenosis, the absence of reflux does not confirm obstruction. In a study by Hudson and colleagues,[80] 84% of obstructed kidneys were on the left, likely the result of extensive left ureteral mobilization and angulation or tension of the left ureter as it crosses behind the sigmoid mesentery. One must also be concerned with recurrent cancer as a cause of stenosis because carcinomas tend to develop at the ureterointestinal anastomosis.[81]

Initially, the conduit should be examined endoscopically to rule out recurrent malignant disease. In patients with established percutaneous access, antegrade endoscopy can further aid in defining the nature and extent of the stricture. The surgeon is then faced with choosing between endoscopic and open treatment. Endoscopic management by antegrade or retrograde methods is discussed in detail elsewhere in the text. Although endoscopic management is increasingly popular, high failure rates are noted unless the stricture is short and uncomplicated.

In the setting of an uncomplicated, short (<1 cm) stricture, most patients should be managed initially with an attempt at endoscopic treatment. The lumen of the stricture should be identified endoscopically. For endoscopic repair, we favor an antegrade approach because the patient is left with a nephrostomy tube as a safety mechanism. If endoluminal ultrasound technology is available, this technique is generally useful. Blind cutting procedures should be avoided because the anastomosis is often directly next to bowel or vascular structures. The ureter should be stented for 6 weeks following stricture incision. If the stricture is >1 cm long, it may be wise to consider open repair initially.

During open reimplantation of a strictured ureteroileal anastomosis, it is best to place an antegrade stent to the level of stricture. The distal ureter is often encased in fibrotic reaction, particularly in the setting of previous leak or infection, and placement of antegrade stents can allow the surgeon to identify the ureters in an otherwise nondiscernible surgical plane. A catheter is placed in the conduit for similar reasons. The distal ureter must be mobilized, but extreme caution should be taken to avoid devascularization of the healthier proximal ureter. In cases of severe periureteral scarring, it is often preferable to excise the stricture, limit mobilization of the proximal ureter, maximally mobilize the conduit, and bring the conduit to the more fixed segment of viable ureter. We also recommend sending the distal ureteral margin for frozen section pathologic evaluation. If malignant disease is identified, a larger segment of ureter should be resected to achieve a cancer-free ureteral margin. For long stricture defects, numerous surgical options exist, including ileal interposition, transureteroureterostomy, renal autotransplantation, and, on rare occasion, nephrectomy.

When the ureteroileal stricture is identified late and the residual renal unit is nonfunctioning, nephroureterectomy is the treatment of choice. This is particularly true in the setting of underlying urothelial malignant disease because a nonfunctioning obstructed upper tract moiety is difficult to follow-up for recurrent malignant disease.

FATE OF THE KIDNEY

During the preoperative evaluation, the status of the patient's renal function should be evaluated by sending blood for BUN and creatinine. One of the primary goals of conduit surgery is the preservation of renal function. In patients with a serum creatinine level >2.5 ng/mL or significant renal disease on radiographic studies, a short conduit should be created to help decrease stasis and to minimize electrolyte abnormality.

Pyelonephritis and Renal Damage

The rate of early pyelonephritis ranges from 1.8% to 3.1%, whereas the rate of late pyelonephritis ranges from 3.1% to 13%.[35,69] A reduction in the incidence of pyelonephritis has been reported in contemporary series, perhaps owing to improved technique and better perioperative antibiotics. In early series, Bricker[50,51] observed that ≤33% of his patients suffered from early pyelonephritis. Madersbacher and colleagues[78] noted that 23% of their patients who had ileal conduits had symptomatic urinary tract infections severe enough to lead to hospital admission. These investigators observed acute or recurrent pyelonephritis in 15 of 131 (11%) patients; this complication was associated with postrenal obstruction caused by anastomotic strictures, stomal stenosis, or urolithiasis in 13 of these patients. Recurrent urinary tract infections without clinically overt pyelonephritis were seen in 10 of 131 (7%) patients, and urosepsis occurred in five (4%) patients, associated with upper tract dilatation in four of these patients. Gburek and associates[79] observed pyelonephritis as an early complication in 6% of their patients and as a late complication in 2% of their patients.

Gilbert and associates[38] followed a cohort of 1565 patients, 80% of whom received an ileal conduit. Within 5 years, over 16% of patients suffered renal failure or impairment. The authors also noted a higher incidence of these renal complications among patients who received a conduit diversion rather than a continent diversion. This may reflect a selection bias, as patients with preexisting kidney disease, or risk factors for such, would be less likely to undergo continent diversion. Regardless of the findings of the study, conduit is still considered the diversion of choice in patients with limited renal reserve preoperatively.

Refluxing Versus Nonrefluxing Anastomoses

The question whether a nonrefluxing ureterointestinal anastomosis has any added benefit in conduit surgery has been the topic of much debate. Although early experiments suggested renal compromise in the setting of a refluxing moiety,[82] little clinical evidence exists to support this view. Kristjansson and associates[83,84] found no difference in glomerular filtration rate or stricture between refluxing and nonrefluxing anastomoses. A 15% rate of ureterointestinal stricture was noted in each group. Both bacteriuria and renal scarring were more common among refluxing anastomoses. Several investigators demonstrated improvement

in hydronephrosis in the majority of patients when nonrefluxing anastomoses were used.[85,86] Stein and associates[87] reported on 105 children who were followed up for 16.3 years after construction of a nonrefluxing colon conduit. These investigators noted a 65.3% incidence of pyelonephritic changes, a rate comparable to that found in other studies, which reported a rate of change in children of ≤68%. More recently, a randomized controlled study comparing refluxing and nonrefluxing anastomosis in orthotopic neobladders by Skinner and colleagues[88] demonstrated no difference between the two techniques with regard to UTI or renal function, but noted that nonrefluxing anastomoses required a statistically significant higher rate of diversion-related secondary surgical procedures.

In adults, a conduit with freely refluxing ureters is preferable, mainly for ease of follow-up. Studies show no significant difference in renal damage and, most importantly, no difference in long-term glomerular filtration rates when comparing nonrefluxing and refluxing conduits. In patients with refluxing conduits who have persistent pyelonephritis with renal damage, the physician may consider revision to a nonrefluxing colon conduit.

DOUBLE-BARRELED WET COLOSTOMY

The double-barreled wet colostomy (DBWC) is an optional method of urinary diversion for patients in need of total pelvic exenteration (TPE), in an effort to avoid two stomas. DBWC was first described by Carter[89,90] in 1989 and involves a single stoma site for both fecal and urinary diversion. With this technique the sigmoid colon is divided 10–15 cm distal to the site that is to be used as a loop colostomy. This loop ostomy is brought up through the fascia, rectus muscle, and left abdominal wall, and the ureters are reimplanted into the distal colonic segment. The small intestine is left intact, and no gastrointestinal anastomoses are created with this method.

This technique improves upon the morbidity (notably wet diarrhea output) and mortality (up to 9%) seen with the original ureterocolostomy described by Brunschwig and Pierce.[91] The double-barreled technique also carries advantages to the technique of using two separate stoma sites, used frequently in the wake of Brunschwig's findings, due to the fact that DBWC only requires maintenance of one stoma site and that the small bowel remains uninterrupted, with no gastrointestinal anastomoses.

Kecmanovic and colleagues[92] analyzed the records of 38 patients who underwent DBWC, finding a postsurgical morbidity rate of 15.7% with no treatment-related mortality. They did, however, note that two patients had late postoperative complications, which included stenosis of the ureterocolonic anastomosis and conduit necrosis. Chokshi and colleagues[93] compared outcomes of 43 patients who underwent DBWC to 10 patients who received IC in the context of total pelvic exenteration. While they found a higher rate of DBWC morbidity than Kecmanovic (possibly due to a stricter definition of postoperative morbidity), they reported no significant differences in morbidity or mortality as compared to conduit. Interestingly, they noted that 26% of patients with DBWC developed enteric fistulas while none did in the IC group. The two groups had no significant differences in terms of incidence of pyelonephritis, urinary leaks, or urinary fistula.

While prospective studies are needed to further compare the complication rates and quality of life associated with DBWC to other forms of urinary diversion, DBWC appears to be the best diversion option for patients requiring TPE, given early studies demonstrating comparable or improved complication profiles to the alternatives and the relative advantage of a single stoma site.

BACTERIOLOGY OF THE ILEAL CONDUIT

Guinan and colleagues[94] reported on the bacterial milieu of the ileal conduit. The native ileum before creation of a conduit was sterile in nine of 10 patients, and one of 10 grew fungus. Postoperatively, 74% of conduits had urine cultures demonstrating bacterial growth. The most common infectious organism was *Proteus* followed by *Pseudomonas* and *Escherichia coli*. These investigators found IVP changes in 67% of infected conduits but no significant correlation between urinalysis and culture results. The changes seen were most pronounced in the presence of *Proteus* or *Pseudomonas* infection.

In general, we do not treat asymptomatic urinary tract infections in patients with conduits, in order to avoid selection of antibiotic resistance over time. We do recommend treating patients with significant asymptomatic bacteriuria ($>10^5$ organisms) in the setting of *Proteus* and *Pseudomonas* infections. Obviously, aggressive treatment is indicated in individuals with pyelonephritis or systemic signs of illness such as fever or leukocytosis. The surgeon must ensure that the conduit is adequately draining, to minimize reflux and the potential for pyelonephritis in the patient with asymptomatic bacteriuria.

OTHER POTENTIAL COMPLICATIONS

The incidence of duplex ureters found on autopsy is 0.3–2.5%.[95,96] The presence of this condition, if unknown preoperatively, can greatly compromise the outcome of conduit surgery. Careful examination of preoperative imaging studies is essential for the recognition and management of the duplicated ureter. When this condition is recognized, the ureters can be implanted separately or together with a Wallace-type anastomosis. Another unfortunate but uncommon complication is conduit-enteric fistula. The finding of decreased output, severe watery diarrhea, and fecaluria can lead to the diagnosis of a fistula.[97]

Stomal varices are another rare and problematic complication. Varices are usually seen in patients with cirrhotic or metastatic liver disease. These patients usually present with gross hematuria coming from the mucocutaneous junction and can usually be treated by correcting the underlying coagulopathy.

Occasionally, the use of coagulation or techniques to oversew the varices may be necessary. Transjugular intrahepatic portosystemic shunts have been used to correct the underlying portal hypertension and to stop the bleeding in these patients.[98]

References

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Chapter 45 Questions

1. A patient presents with a reducible parastomal hernia 1 year after conduit urinary diversion. He denies pain, but is concerned because an inguinal hernia he had 3 years previously required immediate intervention. The most appropriate next step is:
   a. Repair the fascial defect with mesh
   b. Recommend the patient try a support belt
   c. Relocate the patient's stoma
   d. Repair the fascial defect primarily, without mesh
   e. Change the patient's stomal appliance

2. A patient with multiple sclerosis develops stomal stenosis at the level of the fascia. What is the most appropriate next step in managing this patient?
   a. Balloon dilation of stenotic segment
   b. Relocation of the stoma
   c. Change the patient's stomal appliance
   d. Trial of antispasmodic medication
   e. Surgical excision of stenotic segment

3. A patient with an ileal conduit presents with a urine leak 11 days after radical cystectomy. The most likely cause of this complication is:
   a. Ileal segment necrosis
   b. Urine eroding through conduit staple line
   c. Improper surgical technique in formation of ureteroileal anastomosis
   d. Erosion of preexisting stone through ureteroileal anastomosis
   e. Ischemic ureteral necrosis

4. Which of the following strategies is most effectively employed in patients with limited renal reserve undergoing conduit urinary diversion?
   a. Shortening the length of the conduit
   b. Antirefluxing ureteroileal anastomosis
   c. Placing the conduit on tension
   d. Freely refluxing ureteroileal anastomosis
   e. Parker-Kerr sutures

5. Which of the following describes the best initial management of a ureteroileal stricture?
   a. Observe for 4 weeks
   b. Surgical excision of stricture
   c. Endoscopic examination to rule out recurrent malignant disease
   d. Reimplantation of strictured ureteroileal anastomosis
   e. Retrograde stenting of anastomosis

6. In patients with a duplicated ureter, what is the most appropriate course of surgical management?
   a. Excision of the upper moiety
   b. Excision of the lower moiety
   c. Nonrefluxing anastamosis
   d. Wallace anastomosis
   e. End-to-side anastomosis of lower moiety to upper moiety

7. All of the following are early signs of conduit necrosis EXCEPT:
   a. Dusky-appearing stoma
   b. Hyperphosphatemia
   c. Metabolic acidosis
   d. Stomal retraction
   e. Oozing from stoma

8. A patient who underwent ileal conduit urinary diversion 1 year previously comes in with hyperkeratotic skin, but no signs of decreased urine outflow. What is the appropriate next step in management?
   a. Catheter drainage of conduit
   b. Surgical excision of hyperkeratotic skin
   c. Cauterization of the hyperkeratotic skin with silver nitrate
   d. Alkalinization of the urine
   e. Change the stomal appliance

9. A 77-year-old patient who has previously undergone radiation for prostate cancer treatment has now been diagnosed with muscle-invasive bladder cancer. He lives independently, but notes that he requires help with some activities of daily living. Which of the following is the most appropriate urinary diversion for this patient?
   a. Ileal orthotopic neobladder
   b. Indiana pouch
   c. Ileal conduit
   d. Transverse colon conduit
   e. Double-barreled wet colostomy

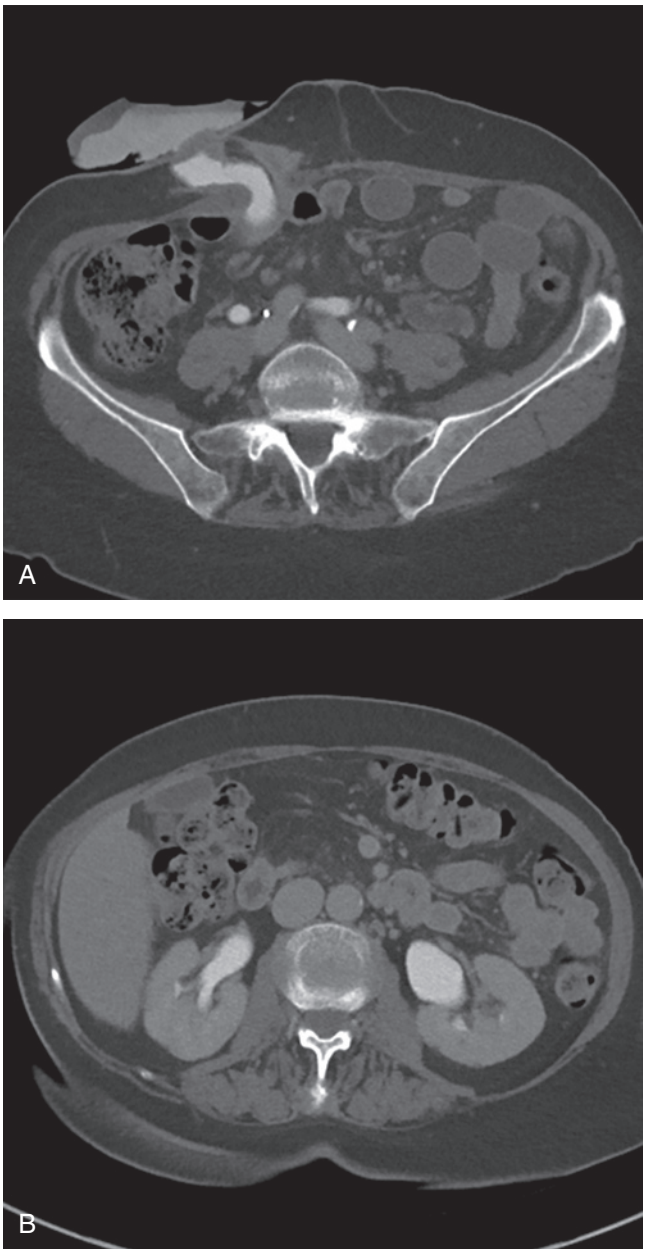
10. An obese patient is noted intraoperatively to have increased tension on his conduit. All of the following techniques can be used to elongate the conduit EXCEPT:
    a. Turnbull loop stoma
    b. Proximal mesenteric incision
    c. Distal mesenteric incision
    d. Defatting
    e. Abdominoplasty

Case Study 1

A 75-year-old woman who underwent radical cystectomy and ileal conduit diversion 5 years ago presents for follow-up care 2 years postoperatively with a stable, easily reducible parastomal hernia that she developed roughly 1 year after surgery. She has not noticed any changes in urine output. She denies changes in bowel habits.

1. A follow-up surveillance CT scan (Case Fig. 45.1) shows a parastomal hernia, but no proximal hydronephrosis. Urographic phase CT is as follows:

   The best management option for this patient is:
   a. Surgical revision of stoma
   b. Have patient manually reduce stoma four times per day
   c. Send patient to general surgeon
   d. Consider use of a belted abdominal binder
   e. Intermittent catheterization of stoma

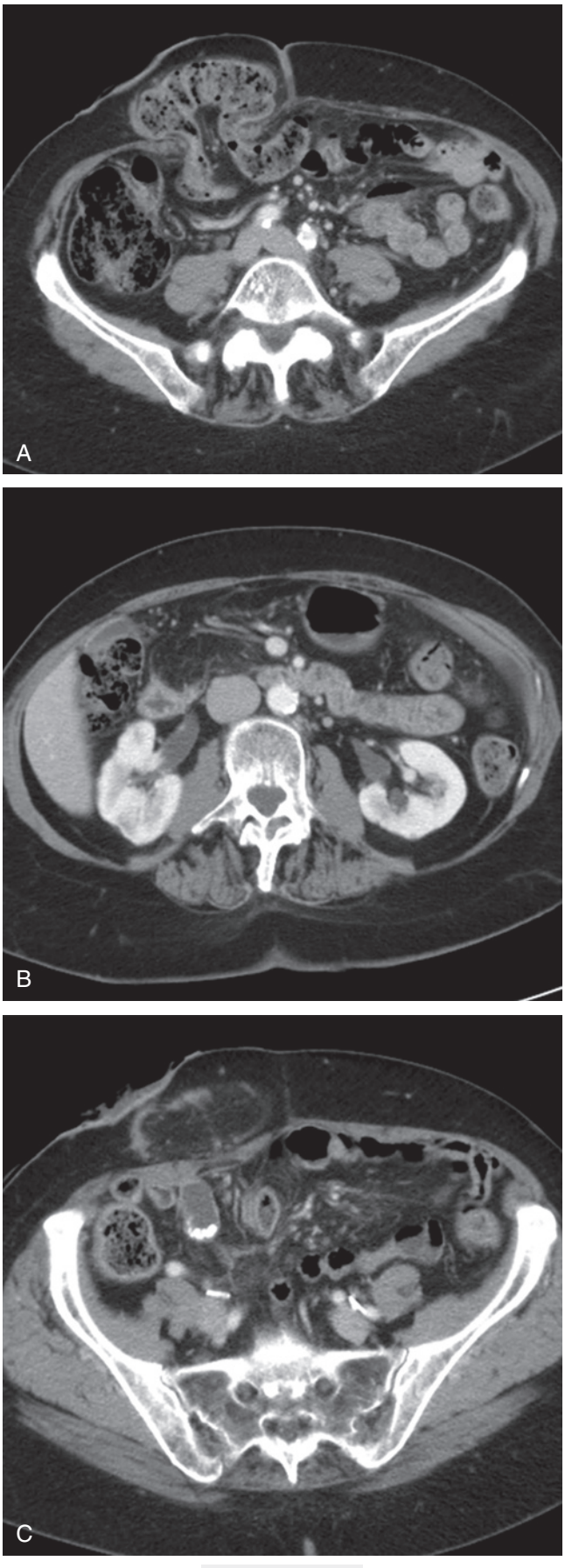


Case Figure 45.1

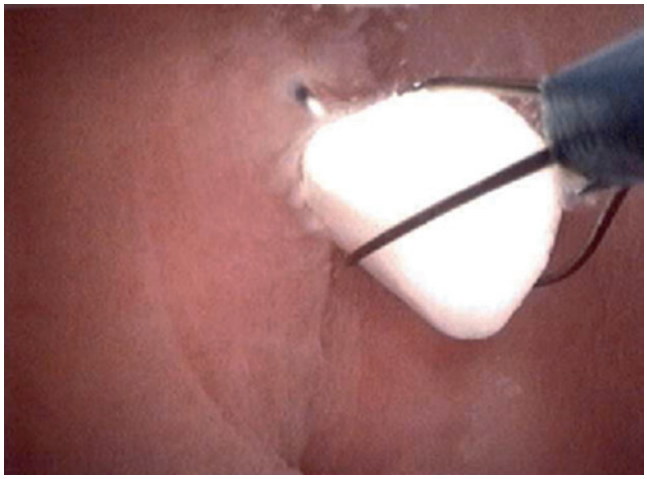
2. Two years later the patient returns. Her parastomal hernia is slightly increased from the previous visit. She has undergone a surveillance CT (Case Fig. 45.2) demonstrating worsening of the hernia, stable upper tracts, and several small stones in the ileal conduit.

   The most appropriate next step in management is:
   a. Continue conservative management of parastomal hernia
   b. Cystoscopy of the ileal conduit and surgical treatment of stones
   c. Stomal revision
   d. Potassium citrate
   e. Conversion to colon conduit

3. The patient is brought for surgical treatment of her stones and the image (Case Fig. 45.3) is captured:



Case Figure 45.2



Case Figure 45.3

Which of the following steps could have been taken to lower the risk of stone formation?
a. Urine acidification
b. Use of nonabsorbable sutures
c. Parker-Kerr suture
d. Phosphate supplementation
e. Potassium citrate

4. Which of the following is the most likely mechanism of stone formation in this patient?
a. High calcium diet
b. Renal failure leading to secondary hypercalcemia and subsequent hypercalciuria
c. Urinary stasis leading to increased chloride and bicarbonate exchange with compensatory hypercalciuria
d. Metabolic alkalosis secondary to urinary retention
e. Excessive oxalate ingestion

5. If the patient were to develop recurrent symptomatic stones, which of the following would be the most appropriate treatment option?
a. Timed catheterization of the stoma
b. Stomal revision
c. Surgical treatment of the stones
d. Conversion to a continent cutaneous diversion
e. Dietary calcium restriction

Case Study 2

A 68-year-old male undergoes an uncomplicated cystoprostatectomy and ileal conduit diversion. In the recovery room, his stoma is dusky and purple, and he is oliguric and mildly tachypneac. His labs demonstrate, normal electrolytes, mild lactic acidosis and a hemoglobin of 9.7.

1. The most likely explanation for his dusky stoma is:
a. Myocardial infarction
b. Venous congestion
c. Portal hypertension
d. Mesenteric ischemia
e. Infarcted conduit

2. Over the next 2 hours, his stoma becomes darker and begins to ooze dark blood. He remains mildly tachypneic, but is hemodynamically stable with normal blood pressure and heart rate of 82. A blood gas shows improvement in his metabolic acidosis, but mild acidosis remains. If concerned regarding ischemia of the conduit, the next step is:
a. CT abdomen
b. Remove sutures in stomal maturation
c. Loop endoscopy
d. Laparoscopic evaluation of the conduit
e. Re-exploration and revision

3. In managing a stoma with edema and venous congestion, the most important early postoperative maneuver is:
a. Lowering blood pressure
b. Incision of the stoma
c. Placement of loop catheter
d. Diuresis
e. Percutaneous nephrostomy diversion

Answers

1. **b.** Surgical repair of parastomal hernias is difficult and not indicated unless the patient is symptomatic. Rubin and associates[59] found that 76% of patients recurred after fascial repair and 33% after stomal relocation, with 63% of patients suffering a postoperative complication. Given the high morbidity associated with revision surgery, conservative measures are indicated for patients with asymptomatic parastomal hernias.
2. **d.** Patients with neurologic conditions can develop stenosis from muscular spasm causing a kinking of the conduit. These conditions are often responsive to antispasmodic medication. This conservative measure should be tried before considering surgical intervention.
3. **e.** Patients with a urine leak 10–14 days after surgery usually have ischemic ureteral necrosis. Conservative measures can be attempted first, with some authors suggesting that patients can wait up to 3 weeks for surgical intervention, as many of these leaks self-resolve.
4. **a.** A shorter conduit length reduces the amount of contact between urine and the bowel, thus reducing metabolic abnormalities associated with the conduit. Antirefluxing ureteroileal anastomoses have not been shown to improve renal outcomes relative to patients with freely refluxing ureteroileal anastamoses for patients undergoing conduit diversion.
5. **c.** After a ureteroileal stricture has been diagnosed, the first step of management is endoscopy to rule out recurrent malignancy. Most strictures under 1 cm can be repaired endoscopically, and a stent should be placed by antegrade approach and remain for 6 weeks. Strictures over 1 cm are more likely to require open surgical revision.
6. **d.** In patients with a duplicated ureter, a condition which should be diagnosed preoperatively with imaging, either a Wallace anastomosis or separate implantation with Bricker anastomoses for both ureters is indicated. A Wallace anastomosis is best used, however, in that it allows reimplantation without separation of the duplicated ureter.

7. **d.** While the stoma can appear dusky in the days immediately following surgery, persistent duskiness is likely a sign of conduit necrosis. In cases of conduit necrosis, the patient should be brought back to the operating room for exploration, resection, and replacement of the conduit.
8. **a.** Alkaline urine is one of the major causes of hyperkeratosis. A catheter should be placed to avoid urine contact with the skin and a heat lamp used twice daily 12 inches from the skin. Further, oral vitamin C or acetic acid washes can be utilized to acidify the urine and site of hyperkeratosis.
9. **d.** Urinary diversions involving segments of ileum are less than optimal in this patient. Previous pelvic irradiation can cause damage to the distal ileum and thus make the tissue more friable and less amenable to healing. Due to the patient's age and functional limitations, orthotopic and continent cutaneous diversions are not ideal, as the patient may not be able to handle the regular management of these diversions. The transverse colon is the segment of bowel farthest away from this patient's radiation site, and transverse colon conduits have similar functional outcomes to ileal conduits.
10. **b.** While some authors have called for a distal mesenteric incision to reduce tension on conduits, the technique does carry an increased risk of devascularization of the diversion. It should be noted that while defatting is a useful technique for lengthening the conduit, it is important that the mesentery is not tucked under the skin edge, as this can lead to poor appliance fit and ultimately stomal stenosis.

CASE STUDY 1

1. **d.** Conservative management is indicated in the case of a nonsymptomatic parastomal hernia. The lack of hydronephrosis on urographic phase CT indicates only a mild obstruction, and the patient only needs to be given something for decompression of the conduit. Stomal revision has a high rate of failure and carries with it additional surgical morbidity.
2. **b.** Up to 20% of patients with urinary conduit develop stone formation. Potassium citrate may be appropriate in the prevention of stone formation. In this case, however, the patient has evidence that stones are causing obstruction and thus they should be treated. Stomal revision is unnecessary at this time, although the patient should continue efforts to decompress the parastomal hernia.
3. **c.** The stone has formed along a retained staple in the conduit. A Parker-Kerr suture helps prevent contact between the staple line and urine, which may lower the risk of calculi formation. Urine alkalinization with Shohl's solution or potassium citrate could have been useful in the prevention of this stone. Nonabsorbable sutures, like retained staples, are implicated in stone formation.
4. **c.** Urinary stasis is believed to lead a metabolic acidosis, in which bone is used as a buffer. This subsequently leads to hypercalciuria and stone formation in the conduit. There are no signs that this patient has renal failure, and her diet is unlikely the primary driver of stone formation. In fact, dilatation of the conduit, noted in 2013, is suggestive of urinary stasis due to mild obstruction.
5. **b.** While catheterization is useful in the prevention of stone formation, it is an insufficient measure in the treatment of a patient with recurrent symptomatic stones. In this case, the patient should undergo stomal revision to remove the obstruction caused by her parastomal hernia. Surgical treatment of recurrent stones is not indicated, as the patient is likely to require frequent intervention.

CASE STUDY 2

1. **b.** In this patient, the uncomplicated nature of his surgery along with his clinical presentation makes simple venous congestion the most likely cause of his stomal discoloration. While ischemia is feasible, in the absence of systemic signs of infarcted or ischemic bowel such as hemodynamic instability, severe acidosis, or electrolyte disturbance, it is less likely. Simple observation with fluid resuscitation is appropriate.
2. **c.** In this case, given the general low suspicion of ischemia, re-exploration would not be indicated. Loop endoscopy can provide a sense of whether ischemia is present by determining if subfascial mucosa is pink or dark and dusky. Pink mucosa below the fascia would indicate venous congestion of the distal conduit due to edema and entrapment at the fascial level. This will generally resolve with conservative management.
3. **c.** Placement of a loop catheter will ensure adequate drainage of the conduit, thereby allowing a gradual decline in edema, distal obstruction, and venous congestion, while avoiding loop distention and secondary stress on the proximal suture lines.

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46 Complications of Continent Cutaneous Diversion

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CHAPTER OUTLINE

Introduction
Prevention of Complications
Application to Robotic Surgery
Early Complications
Urine Leak
Necrosis of the Efferent Limb of the Pouch
Problems Related to Catheterization
Urinary Infection
Bowel Fistula to the Pouch and Other Bowel Complications
General Medical Complications and Complications Unrelated to the Diversion
Late Complications
Infections
Incontinence
Pouch Stones
Kidney Stones
Ureteral Pouch Obstruction
Stomal Stenosis and Difficulty With Catheterization
Conversion From a Continent to a Noncontinent Diversion
Afferent Antireflux Mechanism
Acute Pouch Rupture
Parastomal Hernia
Late Malignant Diseases
Conclusions
Chapter 46 Questions and Answers

KEY POINTS

1. Patient selection is critical to ensure that the type of diversion planned is appropriate for the patient from both a medical and a psychological or social standpoint.
2. Attention to the following technical details during construction of the reservoir can avoid many potential complications:
   - Careful isolation of the segment to be used for the reservoir and complete detubularization of the segment.
   - A direct ureteroileal anastomosis carries the lowest risk of subsequent stenosis.
   - The continence (efferent) limb should be short and straight, and the continence mechanism should be tested during construction to ensure complete continence and ease of catheterization.
3. Early urine leak should be managed with aggressive catheter irrigation, percutaneous drainage of any urinoma, and diverting nephrostomy tubes as needed. Reoperation should be avoided.
4. Most continent cutaneous reservoirs are chronically colonized with bacteria but symptomatic infections are unusual. Late asymptomatic bacteriuria should not be treated.
5. Incontinence from cutaneous continent reservoirs usually requires surgical repair. The exact diagnostic and treatment approach depends on the type of continence mechanism used.
6. Pouch and kidney stones can occur in all types of cutaneous diversions and are usually amenable to endoscopic or percutaneous management.
7. Acute pouch rupture is a rare but potentially fatal complication. Early recognition and surgical exploration are key to successful management.
8. Stenosis of an ileal antireflux mechanism may manifest with silent bilateral hydronephrosis and renal insufficiency.
9. Patients with continent cutaneous reservoirs should have annual evaluation to check for pouch and renal stones or upper urinary tract obstruction.

Introduction

Complications related to radical cystectomy and urinary diversion are very common, occurring in up to 70% of all patients, with 10–15% of complications classified as high-grade.[1,2] Many complications are related to the cystectomy and bowel resection and are common to all types of diversion. These are discussed in Chapter 41. Approximately half of early complications and three-fourths of late complications are related to the diversion itself.[3] Attempts to compare complication rates between the three main types of diversion have shown conflicting results. Although some series have shown no difference in early complications,[4,5] a recent study of patients undergoing robotic cystectomy with extracorporeal diversion showed that continent cutaneous diversion was associated with higher early and late complications compared with both ileal conduit and orthotopic neobladder, as well as an increased likelihood of open surgical revision for late complications. Nonetheless, as the main advantage of continent cutaneous diversion is being generally dry from the beginning after surgery, many patients are willing to accept the increased risk of complications and surgical revision in exchange for avoiding diapers or an external appliance. This chapter focuses on the management of both early and late complications related to continent cutaneous urinary diversion.

Patients undergoing cystectomy should undergo comprehensive preoperative assessment and counseling regarding options for diversion and expectations regarding recovery. Patients being considered for continent cutaneous diversion must have adequate cardiac, pulmonary, and renal function (GFR >40) and be motivated and able to adequately care for themselves and the pouch.[6] Many different techniques are available for constructing a continent form of urinary diversion, including orthotopic neobladders as well as continent cutaneous diversions. Continent cutaneous diversion is specifically indicated for male and female patients undergoing cystectomy who are candidates for continent diversion but in whom an orthotopic neobladder is either contraindicated or not desirable. These indications include the following:

1. The patient prefers continent cutaneous diversion.
2. The external urethral sphincter is incompetent.
3. Severe urethral stricture disease is present.
4. The patient is unwilling or unable to catheterize through the urethra.
5. The patient has chronic bladder or urethral pain or severe interstitial cystitis.
6. The patient has known prostatic stroma invasion with urothelial cancer (relative contraindication to orthotopic diversion).
7. The patient has had previous radical prostatectomy or high-dose radiation therapy to the area of the bladder neck (relative contraindication for orthotopic diversion depending on the severity of the scarring encountered during the surgical procedure).
8. Frozen section biopsy of the urethral margin is positive for urothelial cancer.

Many complications are common to all types of diversion (e.g., early urinary leak and ureteral obstruction), but others are unique to continent cutaneous diversion. These diversions are constructed from isolated colon or ileum with a large variety of continence mechanisms. A full discussion of the various techniques is beyond the scope of this chapter. The following discussion focuses on the most common forms of continent cutaneous diversion, including the Indiana pouch and its variations,[7] the right colon pouch with appendix or tubularized ileal stoma,[8] and the cutaneous T-pouch.[9] The Indiana pouch cutaneous diversion has been recently described in conjunction with robotic-assisted cystectomy, with no significant difference reported in functional outcomes and early and late complications over standard open series.[10] We also discuss the complications associated with the cutaneous Kock pouch,[11] a diversion now rarely performed in the United States but one that still can cause challenging complications in patients who had the diversion in the past. Metabolic complications associated with the use of bowel in the urinary tract are covered elsewhere (see Chapter 5).

Prevention of Complications

Careful surgical technique is the key to minimizing complications related to the continent diversion. The choice of bowel segment must allow for adequate pouch volume. In general this requires approximately 44 linear cm of small bowel or 26 to 30 cm of colon for the reservoir portion. If the available colon length is <26 cm, an additional patch of ileum should be used to enlarge the reservoir.

The segment chosen for the reservoir must be isolated carefully to avoid compromise of the vascular supply of either the reservoir or the remaining bowel. This maneuver is most difficult in patients who have had previous bowel resection. In these patients, it is crucial to take down the previous bowel anastomosis rather than choosing a new site. When a new site is chosen, the risk of vascular compromise of the segment between the old and new bowel anastomoses is high. If appendix is to be used, it is examined for adequate length and girth, and the tip is amputated to ensure that the lumen is patent into the cecum as sometimes the lumen can be obliterated in older patients. Care must be taken not to damage the main blood supply to the appendix during mobilization.[8]

The segment chosen for the reservoir must be opened along its entire length to allow for a low-pressure reservoir (Fig. 46.1).[8,12] In general the segment should be folded and closed to construct a reservoir that is as spherical as possible and provides the maximum volume for the surface area used to minimize the intraluminal pressure. It is critical to use only absorbable suture (or absorbable staples) to close the reservoir because any permanent suture or staples may become a nidus for stone formation. Closure of the pouch in one or two layers should be watertight, and this can be tested intraoperatively.

An antireflux mechanism is generally believed to be important in cutaneous continent diversion because of the very high rate of bacterial colonization.[13] Some of the commonly used antireflux mechanisms include tunneled ureteral anastomoses, the ileocecal valve, the Kock intussuscepted nipple valve, or an extraserosal tunnel (T-pouch).[14,15] Some authors have also reported good results with a refluxing anastomosis.[16]

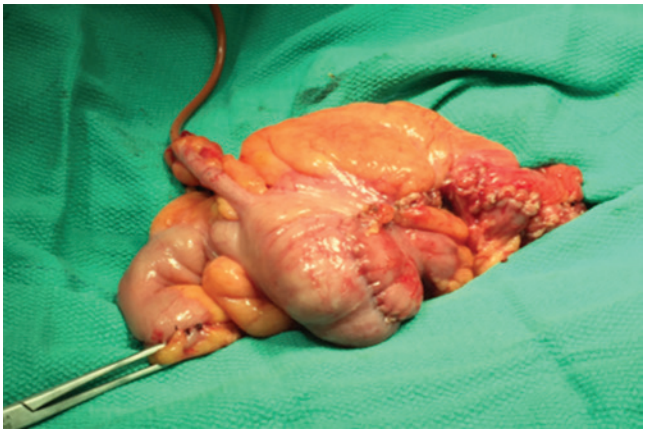


Figure 46.1 Segment of right colon and distal ileum isolated for a right colon pouch with appendix stoma. The entire right colon segment should be incised along one of the taeniae coli to detubularize the bowel completely. The afferent limb distal ileum (held by an Allis clamp) is closed with a Parker-Kerr stitch and otherwise left intact for implantation of the ureters. The appendix (cannulated by a red Robinson catheter) will serve as a catheterizable stoma to the umbilicus. The ileocecal valve acts as the antireflux mechanism.

The choice of technique for the ureteral anastomosis depends on the bowel segment used. We use a stay suture for manipulating the ureter during the anastomosis and avoid grasping it at all with forceps. The ureteral anastomosis with the lowest early and late stenosis rate is the end-to-side ureteroileal anastomosis, with <3% long-term stenosis.[17] This has been our standard anastomosis in the Kock pouch, the Studer and T-pouch ileal neobladders, and the right colon pouch with appendix stoma (using the distal ileum as the afferent limb). A similar direct nontunneled anastomosis to the colon carries a 6% to 7% stenosis rate.[16] The LeDuc method appears to have the lowest stenosis rate for antirefluxing techniques, although results have varied.[18] Tunneled anastomoses into the tinea of the colon carry a rate of stenosis of 10% to 12%.[17] Previous ureteral surgery or radiation therapy increases the risk of subsequent stenosis. In patients who have undergone previous pelvic radiation, it is wise to take the ureters well above the field of radiation and to attempt to use a nonirradiated segment of bowel for the implantation.

Construction of the catheterizable efferent limb and stoma requires careful attention. Regardless of the continence mechanism used, the length of the efferent limb has no impact on continence. Therefore, it should be as short and straight as possible to avoid any redundancy above or below the fascia that could contribute to difficulty with catheterization. At each step in construction of the efferent limb, the surgeon should pass a catheter to ensure that it is smooth and without obstruction.

Stomal stenosis can be minimized by making a V-shaped flap when opening the skin and dropping the skin flap into the spatulated antimesenteric side of the efferent limb when it is matured to the skin.[19,20] This maneuver is performed whether the stoma is in the right lower quadrant or at the umbilicus. With an umbilical stoma it is helpful to excise the majority of the umbilical scar to reduce the risk of later stenosis.

Finally, thoughtful placement of catheters, stents, and drains can minimize problems related to urinary leak in the early postoperative period. All bowel segments excrete a large amount of mucus early on, and this needs to be managed so that catheters continue to drain. We routinely use a 24Fr stiff two-way hematuria catheter to drain the reservoir, placed percutaneously several centimeters away from the stoma. Only a small 12Fr or 14Fr red Robinson or Foley catheter is placed through the stoma as a placeholder. A Foley is less likely to be dislodged but it needs to be protected so that the balloon is not pulling against the continence mechanism. We use 8Fr pediatric feeding tubes to stent the ureters, and they are tied to the larger hematuria catheter within the reservoir so the feeding tubes and hematuria catheter are removed together once the pouch has healed. Alternatively, stents can be passed up to the kidney and then brought into the pouch and out through the pouch wall and skin to drain externally. Finally, a suction drain is placed in the pelvis near the reservoir to drain any urine that might leak from the suture line. This drain may be left in place until the pouch is healed. Nursing staff and later the patient and family are instructed to irrigate the large catheter regularly to keep it free of mucus.

Application to Robotic Surgery

Adaptation of the continent cutaneous diversion to robotic approaches has been recently described. Torrey and colleagues reported on 34 patients who underwent robotic-assisted radical cystectomy followed by laparoscopic mobilization of the colon and extracorporeal construction of an Indiana pouch, with the goal of minimizing the required surgical incision.[10] In this series, early and late complication rates, including hospital stay and transfusion rates, were not improved compared to those reported in open series. A systematic evaluation of factors contributing to complication rates in robotic-assisted cystectomy with extracorporeal diversion showed that continent cutaneous diversion was associated with increased early and late complications compared to ileal conduit or neobladder diversions.[1] Goh and colleagues recently described one of the first techniques for a completely intracorporeal robotic-assisted Indiana pouch construction.[21] The majority of series of robotic-assisted cystectomy published to date include very few cases of continent cutaneous diversion.[22]

Early Complications

Diversion-related complications account for approximately 40% of the total early complications observed in patients undergoing cystectomy and continent diversion.[3,23] The incidence of early complications is not increased with continent diversion compared with ileal conduit.[24–26]

URINE LEAK

It is very common to have some degree of urine leak from one of the suture lines in the pouch during the first few days after the surgical procedure. This is not a true

complication as long as the urine comes out the drain. The leakage may persist for days to weeks but nearly always heals with time as long as good catheter drainage is maintained. More frequent irrigation of the pouch catheter may hasten resolution of the leak. Sometimes the drain is too close to the pouch and is acting as a wick, and a few centimeters withdrawal of the drain can resolve this problem.

An undrained leak is potentially serious and may present with abdominal distention, ileus, decreased urine output, fever, or rising blood urea nitrogen. In this situation, the following measures should be taken:

1. A gravity cystogram under fluoroscopic guidance to confirm proper position of the catheter. This study can also identify the site of extravasation.
2. Computed tomography (CT) scan to evaluate for a large fluid collection in the abdomen or pelvis. If a collection is identified, an additional drain should be placed percutaneously under image guidance. The site of leakage may also be identified if the CT scan is done with intravenous (IV) contrast in the excretion phase.

Diversion of urine with unilateral or bilateral nephrostomy tubes may be required if the leak is severe and persistent, appears to be arising from one or both ureters, or if urine is draining from the wound or has fistulized to another site (e.g., bowel anastomosis or vaginal cuff). This diversion of urine away from the pouch facilitates healing at the site of leakage. The nephrostomy tubes may be left in place for several weeks if necessary. Antegrade studies can confirm resolution of the leak before the tubes are removed. This measure nearly always resolves even the most difficult leak, so it is crucial that the surgeon performing continent diversion have skilled interventional radiologists available to assist in these situations.

A basic principle of management of urinary leaks in the early postoperative period is to avoid attempting open surgical repair. Open exploration and primary repair are extremely difficult in this early period as a result of intense inflammatory reaction. These procedures are rarely successful in achieving a watertight repair. The only situation requiring reoperation is a large, undrained leak that is not amenable to percutaneous drainage. Any repair of a persistent leak should be delayed if possible to 8 to 12 weeks after the initial surgical procedure, once inflammation has had an opportunity to decrease.

NECROSIS OF THE EFFERENT LIMB OF THE POUCH

Necrosis of the efferent limb of the pouch should be an extremely rare event if care is taken in mobilizing the bowel and constructing the catheterizable efferent limb. The most distal portion of the efferent limb or appendix has the most tenuous blood supply, so slight duskiness at the mucocutaneous border is not uncommon shortly after the surgical procedure. However, if there is concern that the limb looks necrotic, a flexible cystoscopy can be performed. No intervention is necessary if healthy mucosa is encountered in the efferent limb. Reoperation with construction of a new efferent limb is required in patients with total necrosis of the limb.[23]

PROBLEMS RELATED TO CATHETERIZATION

Mucus production is universal in continent diversions made from small or large bowel. All cutaneous pouches should be regularly irrigated to clear the mucus. Mucus plugging of catheters can usually be managed by aggressive irrigation. Gross hematuria with clots rarely complicates a continent diversion during the initial healing phase. Continuous irrigation and correction of any coagulopathy are helpful, and rarely an endoscopic evaluation to identify and cauterize a bleeding vessel might be necessary. If a catheter is dislodged or must otherwise be replaced in the early postoperative period, a fluoroscopic cystogram should be performed to confirm proper position of the new catheter.

URINARY INFECTION

Febrile urinary tract infections are relatively common in patients in the early postoperative period, especially while catheters are still in place. In a review of 27 perioperative mortalities in cystectomy patients over a 30-year period, eight cases were caused by overwhelming sepsis. Many of these patients had urine or bowel leak, and all had reoperations during their hospital course.[27] Fungal infections and resistant bacterial infections have become more common in hospitalized patients and can cause significant morbidity and death, especially if not recognized early. Long-term antibiotics have not generally been used because of induction of highly resistant organisms, but we will reintroduce antibiotics at the first sign of fever. We often also add antifungal medications to the treatment of hospitalized patients who become febrile or have leukocytosis after the first week in the hospital in the absence of other obvious sites of infection, even before the urine culture grows yeast. One must suspect resistant organisms in acutely ill postoperative patients and treat them accordingly.

BOWEL FISTULA TO THE POUCH AND OTHER BOWEL COMPLICATIONS

A fistula to the pouch is heralded by the presence of fecal material in the urinary drainage bag or drain, possibly associated with fever or pain. It is generally caused by a leak from the bowel anastomosis or a missed bowel injury. The recommended initial management in the early postoperative setting is bowel rest with parenteral nutrition. CT scan is advisable to ensure that an undrained abscess is not contributing to the problem. Again, early surgical exploration is difficult in the setting of inflammatory postoperative reaction and should be avoided in favor of delayed repeat exploration and repair if the fistula does not resolve within 4 to 6 weeks of bowel rest.[28] An asymptomatic fistula is occasionally identified on routine postoperative imaging. In the absence of symptomatic infections or diarrhea these can be managed conservatively.

Other early bowel complications include prolonged ileus, partial or total small bowel obstruction, gastrointestinal bleeding (usually resulting from stomach or duodenal ulcers), *Clostridium difficile* enterocolitis, and pelvic abscess caused by a bowel leak. The problems are common to all types of urinary diversion and to most other major abdominal surgical procedures involving bowel resection. The

incidence of prolonged postoperative ileus has been markedly reduced in recent years by adoption of ERAS (enhanced recovery after surgery) techniques, including avoidance of bowel preparation, careful fluid management, minimized narcotics, and the addition of alvimopan, a μ-opioid antagonist.[29] Management is nonoperative whenever feasible, with endoscopic and percutaneous techniques used as needed. Taken together, these types of gastrointestinal complications account for approximately 30% of all early complications in patients undergoing cystectomy and diversion.[1,2]

GENERAL MEDICAL COMPLICATIONS AND COMPLICATIONS UNRELATED TO THE DIVERSION

Many early postoperative complications result from cystectomy itself rather than from the specific type of diversion performed. These complications include hemorrhage, thrombotic events, and medical complications such as cardiac or pulmonary problems. Patients undergoing cystectomy and diversion have an average age of almost 70 years, and an increasing proportion of our patients receiving treatment are older than 80 years of age. Previous smoking behavior often contributes to significant cardiac and pulmonary comorbidities in these patients. Other problems that increase complications include diabetes, poor nutrition, obesity, limitations to mobility, and renal insufficiency. General medical problems account for over half of the early complications observed following cystectomy.[3] It is important to optimize the patient's other medical conditions preoperatively whenever possible.

Late Complications

INFECTIONS

Colonization of the urine with bacteria is always present in patients with a continent cutaneous reservoir on intermittent catheterization.[6,26,30] Conversely, late serious infections such as pyelonephritis and sepsis are relatively rare in the absence of upper tract obstruction or stones. *Therefore, it is very important not to subject patients to unnecessary antibiotics for asymptomatic bacterial colonization.* Patients and their primary care physicians need to be instructed in this principle.

Patients with cutaneous diversion who have symptomatic infections should be evaluated for completeness of emptying, hydronephrosis, and the presence of stones in the pouch or in the kidney. Occasionally patients with no anatomic abnormality may develop recurrent symptomatic infections that cause pain over the pouch or fevers, often preceded by very foul-smelling urine. This presentation appears to be much more common in patients with a history of interstitial cystitis than in patients with malignant disease. Daily pouch irrigation with saline solution (or even a very dilute bleach solution) should be recommended. Chronic low-dose antibiotic suppression may be helpful. A useful approach for patients who suffer recurrent symptomatic infections is to have them take a very short course of antibiotics (e.g., 2–3 days of a sulfonamide or fluoroquinolone) at the first sign of symptoms, no more than once or twice per month. Longer-term antibiotic use risks colonization with highly resistant organisms.

INCONTINENCE

Incontinence in a continent cutaneous diversion affects on average 15% of patients and can occur at any time.[31] Occasionally what is interpreted as urine leakage is actually mucus drainage from the efferent limb (which is unavoidable) or failure to pinch the catheter on withdrawal, thus leaving a small amount of urine in the efferent limb. Persistent leakage, however, is due to a failure of the continence mechanism. Endoscopic injection of bulking agents has been described, but resulted in complete resolution of leakage in a minority of patients.[32,33] Although some patients may opt for more frequent catheterization, a pad, or an external collection device as management of smaller leaks, most patients with significant leakage ultimately require open surgical repair.[34] The diagnostic approach prior to surgical correction depends on the type of urinary diversion that had been constructed, but generally includes endoscopy of the pouch and a cystogram with drainage views. Urodynamic studies should be considered in pouches constructed from colon, which is more likely to have high-pressure waves and be amenable to pouch augmentation with a patch of ileum.

The following are some considerations for each type of diversion:

1. *Kock pouch to skin*. These procedures are now rarely performed in the United States, but some older patients still have a cutaneous Kock pouch and may require treatment. Incontinence results from incompetence of the intussuscepted nipple valve possibly caused by extussusception of the valve, stones on the nipple valve, or a fistula through the midpoint of the valve (e.g., by traumatic catheterization). Flexible endoscopy allows retroflexion of the scope and identification of the problem at the efferent valve. Detubularized ileal reservoirs generally have reliable low-pressure systems, so urodynamic evaluation is not necessary. Occasionally an extussuscepted nipple valve can be restapled to the back wall of the pouch, or a stone can be removed and the nipple repaired. However, it is often preferable to replace the efferent continence mechanism completely with a new limb (e.g., using a T-limb or the Mitrofanoff principle).[34,35]
2. *Indiana pouch and its variations.* Incontinence in this type of right colon pouch is generally the result of incompetence of the reinforced ileocecal valve. It may also be caused by a high-pressure reservoir, especially if the colon was not adequately detubularized; thus urodynamic studies should be performed prior to a planned repair. Repair may be accomplished by mobilizing the pouch and reinforcing the ileocecal valve with additional Lembert silk sutures around the base, with the addition of an ileal patch onto the pouch if high-pressure contractions were seen on urodynamic study.[36] Alternatively, a new efferent limb can be constructed. Temporary improvement may occasionally be achieved with endoscopic subcutaneous injection of collagen around the base of the efferent limb near the ileocecal valve.

3. *Appendix or tapered tunneled ileal segment.* Incontinence in these systems is unusual, but it may result from loss of the reinforced tunnel at the base of the appendix or erosion of the appendix from an indwelling catheter. Again, flexible endoscopy and urodynamic studies to identify high-pressure contractions are helpful in defining the problem. Repair may be achieved by constructing a new tunnel at the base of the appendix (using the Mitrofanoff principle) or by making a new efferent limb with a tapered ileal segment. Injection of collagen in the submucosa at the base of the appendix has also occasionally been helpful.
4. *Extraserosal tunnel (T-limb).* Incontinence is usually caused by loss of the extraserosal tunnel, as occurs when the permanent silk backing sutures pull through the serosa, most likely due to trauma from daily catheterization.[14] It may be difficult to recognize this situation convincingly on a cystoscopic examination or cystogram because the problem is on the outside of the reservoir. Urodynamic studies should be performed preoperatively if the pouch was made from colon to identify high-pressure contractions. To repair the continence mechanism, either the tunnel can be reinforced with a new set of backing sutures or an entirely new efferent limb can be constructed.

POUCH STONES

Stones can develop in any continent diversion, with an incidence that varies between 5% and 10% and increases over time.[37] The incidence is highest in pouches constructed using surgical staples (such as the Kock pouch),[36] but it is also seen in pouches without any foreign body[38] and is related to mucus production, chronic bacterial colonization, and incomplete emptying. As a result, all patients with a continent diversion should be followed with at least yearly plain radiographs, CT scan, or cystogram for surveillance of stones while still small and amenable to endoscopic management.

There is a higher incidence of stones in continent cutaneous diversions than in neobladders, probably because of a higher rate of bacterial colonization and elevated post-void residual of urine leading to stasis.[39] The incidence appears to increase with longer follow-up, and patients with a history of one pouch stone have a high recurrence rate and should be followed more diligently. These patients should also be encouraged to irrigate their catheters more regularly and may benefit from potassium citrate supplementation to reduce future stone formation.[39,40]

Stones in a pouch should be suspected in a patient with hematuria, pain, difficulty with catheterization, urinary incontinence, or recurrent symptomatic urinary tract infections. The stones are almost always radiopaque and can be identified on cystogram or CT scan without contrast. It is crucial for the urologist to review these films personally, as many radiologists are unfamiliar with the anatomy of this type of reconstruction and may easily miss the presence of stones in the pouch on plain films (Fig. 46.2). It is more straightforward to identify small pouch stones on CT scan, though these may be missed as well (Fig. 46.3). MRI is not sufficiently sensitive for detecting stones in the reservoir.

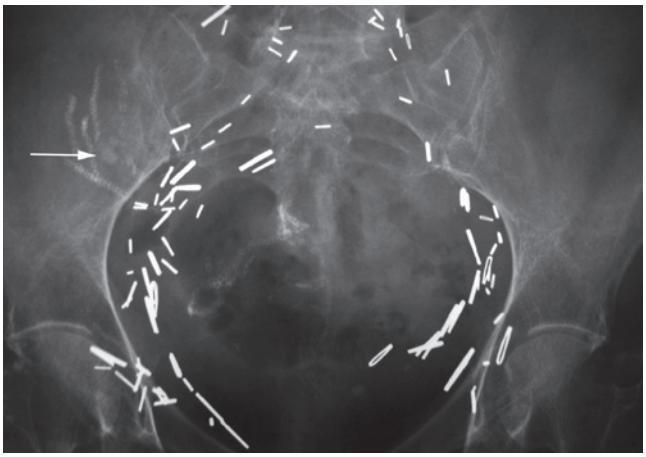


Figure 46.2 Small stones are faintly visible overlying the surgical staples on the efferent intussuscepted Kock ileal nipple valve (arrow). These stones can be missed by an inexperienced radiologist.

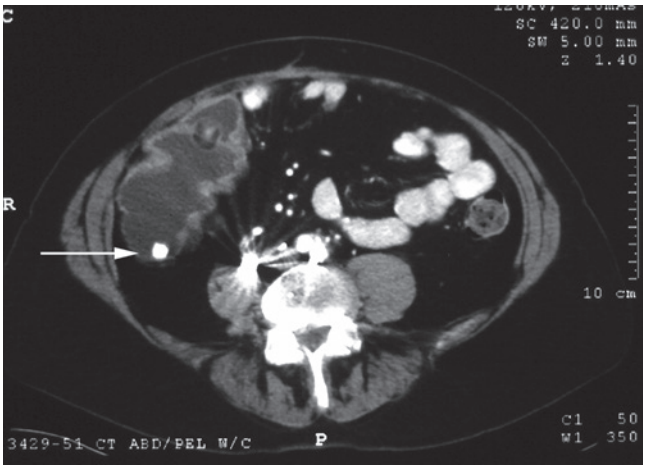


Figure 46.3 CT scan without contrast in the reservoir depicting a 1-cm stone (arrow) in the pouch.

If left untreated, these stones inevitably increase in size and tend to harden in consistency as more stone deposits in layers. Therefore pouch stones should not be observed but rather treated by complete removal at the time of initial diagnosis. The goal of treatment is to remove all fragments without damaging the pouch or its continence mechanism. Fortunately, most pouch stones can be removed endoscopically by using techniques similar to those for removal of large bladder or kidney stones. The availability of versatile endoscopes, both rigid and flexible, and of efficient energy sources such as electrohydraulic, ultrasonic, and pneumatic lithotriptors and holmium lase has allowed efficient fragmentation and removal of stones even through small stomas. Extracorporeal shock wave lithotripsy is not recommended for pouch stones because of the need to remove all fragments to prevent recurrence.

Small stones can be easily retrieved with a flexible cystoscope inserted through the stoma. Such scopes are approximately the same caliber as the catheters used to empty the pouch. Basket removal or lithotripsy followed by basket removal can be performed safely without significant concern

for damaging the continence mechanism. However, because these scopes are smaller than their rigid counterparts, the smaller working channel makes them less efficient for treating larger stones.

For large stones, a rigid scope such as an offset rigid nephroscope or cystoscope provides a large enough channel to break up and remove the stone fragments efficiently. This technique is preferable to flexible endoscopy, and a rigid scope can generally be inserted safely through a stoma under direct vision. Aggressive manipulation of a rigid scope within the efferent limb should be avoided. An Amplatz type access sheath can be used to protect the continence mechanism from damage from repetitive insertion of instruments during the course of the procedure. This device does dilate the efferent limb and stoma, but provides safe access into the pouch without damaging either the mucosa of the efferent limb or the continence mechanism. Use of continuous flow irrigation facilitated by this device decreases the pressures within the pouch, allows for efficient irrigation of stone fragments, and improves visibility during the procedure. The development of permanent incontinence after endoscopy through a stoma is extremely rare.[41] Some patients may find it difficult to catheterize immediately after endoscopic manipulation because of the presence of edema, a complication more likely with rigid than flexible endoscopy. It may be helpful to leave a catheter in the efferent limb for 24 hours after the procedure to allow the edema to subside.

Rigid endoscopy of the stoma should be avoided in certain situations. Appendiceal stomas tend to be too narrow for most rigid scopes and the angle entering the pouch limits manipulation. Small stones in such pouches can be removed with a flexible cystoscope. Larger stones or stones in a difficult location within the pouch are better managed percutaneously.[42,43] This procedure can be safely accomplished as long as one is careful to identify a spot where the pouch is up against the abdominal wall without the intervening bowel. When a percutaneous catheter had been used perioperatively, use of this old scar is generally safe. If any doubt exists, ultrasound or CT scan should be used to identify a safe passage for percutaneous access.[44] Once access is obtained, the tract can be dilated either by balloon dilation or sequential manual dilators. An Amplatz sheath along the percutaneous tract allows access to the pouch and facilitates irrigation and removal of stone fragments. All stone fragments must be extracted or irrigated out of the pouch at the end of the procedure because they may not pass through the catheter and subsequently stick to bowel mucosa and become a nidus for additional stone formation.

Patients who are not followed up with at least annual radiographs may present with very large stones (Fig. 46.4). When stones are more than 3–4 cm in diameter, endoscopic management is difficult and inefficient. In these rare situations, the stones are best managed with a simple open cystotomy lateral and superior to the stoma.[45]

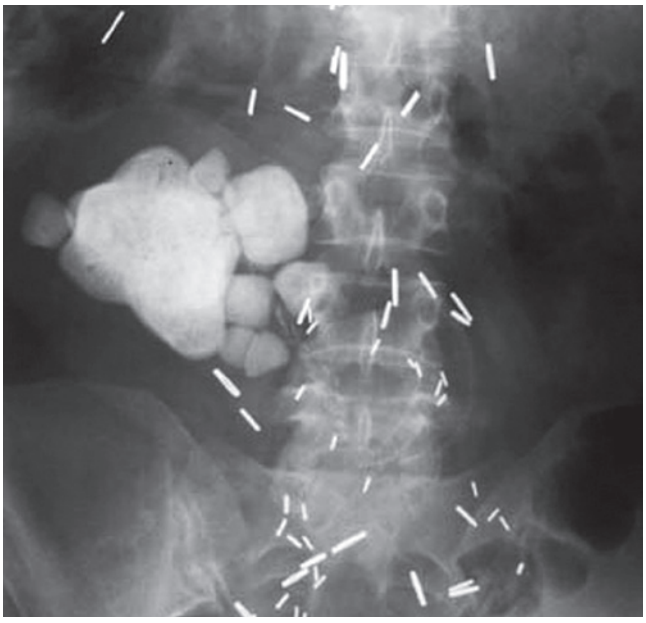


Figure 46.4 Large stones in a continent cutaneous reservoir. These stones are best removed through a small open incision lateral and superior to the stoma rather than with endoscopic techniques.

KIDNEY STONES

Kidney stones are a known complication of urinary diversions for a variety of reasons. Metal staples from a Kock pouch nipple valve may reflux up into the kidney and form a nidus for stone formation. Metabolic derangements from the interposition of intestinal segments and chronic bacterial colonization with urease-producing bacteria can predispose patients to stone formation as well.[46,47] In patients with cutaneous reservoirs, treatment options for managing kidney stones include extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy.[45] In rare instances, retrograde ureteroscopy can be performed through the stoma but the altered anatomy makes access to the upper collecting system extremely difficult and unreliable.

Treatment options depend on the size and location of the stones. Although no absolute size criteria have been determined for this patient population, extracorporeal shock wave lithotripsy is more effective for smaller rather than larger stones. Overall success rates for extracorporeal shock wave lithotripsy have been variable, with overall success rates ranging up to 80%; however, more than 40% of patients required multiple treatment sessions.[48] Larger stones, staghorn calculi, and stones within the ureter are more reliably managed percutaneously either through percutaneous nephrolithotomy or antegrade ureteroscopy.

URETERAL POUCH OBSTRUCTION

The management of ureteroileal stenosis is covered in detail in Chapter 45. As mentioned earlier, the type of ureteral anastomosis is directly related to the risk of subsequent obstruction, with antireflux techniques conferring the highest rates of stenosis. The lowest rate reported is the Leadbetter technique with interrupted ureteroileal anastomoses.[49] Ureteral obstruction can be discovered incidentally, can occur many years after the diversion, and can be asymptomatic. Therefore, patients with urinary diversion need lifelong follow-up for hydronephrosis, even after the risk of recurrent cancer is past. Obstruction may also

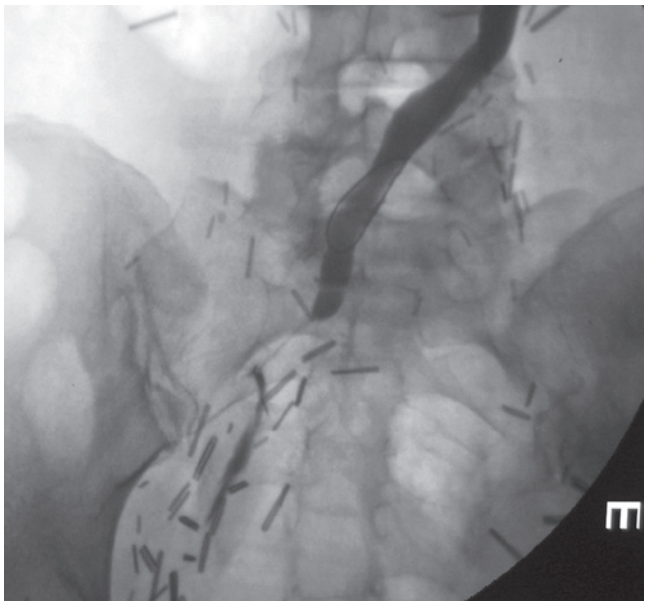


Figure 46.5 Ureteroileal stricture seen on an antegrade nephrostogram. Only a faint sliver of contrast material is seen passing through the stricture. These strictures are more common on the left side and are usually due to ischemia of the distal ureter. Nonetheless, cytologic examination and brush biopsy should be performed to rule out recurrent urothelial carcinoma.

manifest with pain, infection, or renal insufficiency. The differential diagnosis includes ischemic stenosis and recurrent cancer. These disorders can be differentiated to some extent by their appearance on CT urogram or antegrade nephrostogram (Fig. 46.5), cytologic study, or endoscopic biopsy.

Open repair is still considered the gold standard of treatment, with long-term success rates between 76% and 93%.[50–53] However, the morbidity of such repair can be significant, and therefore endoscopic techniques are usually the first line of treatment.

Endoscopic management of ureteral strictures in continent cutaneous diversion usually requires an antegrade approach because it is very difficult to access the obstructed anastomosis from the reservoir. Various endoscopic treatment modalities have been described, including balloon dilation, endoureterotomy, and metal stenting. Success rates vary widely and depend on several factors. Wolf and associates reported the importance of renal function on success rates after endoscopic treatment of nonmalignant ureteroenteric strictures, with endoureterotomy failure in all patients with ipsilateral renal unit function of less than 25%. These investigators also observed that repeat endoureterotomy after a failed procedure was considered only when at least a partial radiographic response occurred and when steroid injections were used.[54] In a review of the literature on endoscopic treatment modalities for ureterointestinal strictures after radical cystectomy, Kurzer and Leveillee concluded that favorable characteristics for success after endoureterotomy included age <60 years, a right-sided stricture, length <1 cm, mild to moderate dilation, use of a ≥12Fr stent, and stenting for >6 weeks.[55] Cumulative success rates showed that balloon dilation had the worst outcome at 18%, in contrast to endoureterotomy at 63% and metal stenting at 83%. No specific cutting modality (i.e., laser, electrocautery, cold knife) appears to have an advantage over another. These investigators also pointed out that an open repair after multiple endoscopic attempts had a lower success rate and higher morbidity than did an initial primary repair.[55] In a recent study involving 74 patients treated for nonmalignant ureteroileal strictures, Schondorf and colleagues reported than open surgical intervention produced better overall results than minimally invasive endoscopic intervention (91% for open vs 26% for endoscopic), particularly for strictures greater than 1 cm (86% for open vs 6% for endoscopic).[52] The authors concluded that the success rate of endoscopic intervention was acceptable only for ureteroileal strictures of 1 cm or less (50%) and that ureteroileal strictures greater than 1 cm should be primarily managed by open surgical revision.[52]

STOMAL STENOSIS AND DIFFICULTY WITH CATHETERIZATION

Stomal stenosis and difficulty with catheterization in the absence of stenosis at the skin occur in 10% to 30% of patients.[31] Stomal stenosis at the level of the skin is particularly common when the appendix is used for the efferent limb, presumably in part due to compromised blood supply at the appendix tip.[20,56] Location of the stoma at the umbilicus can also commonly lead to stenosis. The following sequential steps may be attempted to manage this problem:

1. Office dilation with female urethral sounds, with stoma catheter placement for a few days for additional passive dilation of the skin
2. Office incision of the stenotic skin edge or excision of built-up scar tissue
3. Outpatient Y-V plasty of the stoma by dropping in a new flap of skin
4. Formal revision of the stoma.

Formal revision of the stoma, although more involved, is also the most successful in difficult cases and has the best long-term results. As the efferent limb (appendix or ileum) has usually lengthened significantly several months after the original surgical procedure, it can be mobilized down to the fascia, the old mucocutaneous border excised, and a freshly spatulated stoma constructed with an interposed flap of skin.

Difficulty with catheterization is one of the most vexing problems for patients with a continent cutaneous diversion and causes significant anxiety. When not due to stenosis at the skin, it is usually due to tortuosity of the efferent limb in its course from the skin to the pouch, as true stenosis of the efferent limb other than at the skin level is rare. Often the source of the problem can be diagnosed by simply observing the patient self-catheterizing or catheterizing the patient in the office with the pouch full. Endoscopy of the limb can be helpful in identifying the problem, though it can be challenging in the office setting.

Complete inability to catheterize despite multiple attempts is an emergency. Unfortunately, most emergency physicians have little experience with these types of diversions and are unable to troubleshoot the problem. The urologist should thus not delay in becoming involved. A first attempt should include catheterization with a small 14Fr

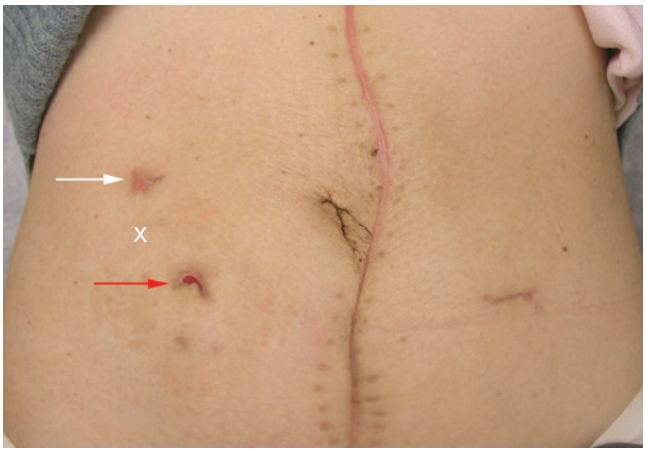


Figure 46.6 Photograph of the abdominal wall of a patient 6 months following cystectomy and nephroureterectomy with a right colon pouch and an appendix stoma. The stoma (red arrow) is located in the right lower quadrant. The scar from the perioperative percutaneous catheter drain that has been removed is lateral and superior to the stoma (white arrow). It is generally safe to drain a pouch percutaneously in the area marked (white X) because no intervening bowel should be present between the stoma and perioperative drain site.

or 16Fr coudé-tip catheter with sufficient lubrication. Flexible endoscopy with passage of a wire is occasionally successful if the stoma is open at the skin level. If these initial attempts fail, the overdistended pouch should be drained percutaneously. This maneuver relieves the patient's pain and may straighten out a kink in the efferent limb. The procedure can be done safely percutaneously with a long 18-gauge or 16-gauge angiocatheter (such as those used for central line placement) a few centimeters to the right and superior to the stoma, given that the right colon and small bowel usually lie medial to the reservoir (Fig. 46.6). A test pass can be made with a fine spinal needle, or bedside ultrasound guidance can be utilized if the location of the pouch is unclear. Once the tip of the angiocatheter is in the pouch, the needle can be removed and the pouch emptied through the soft plastic catheter. If catheterization through the stoma is still unsuccessful with the pouch less distended, a wire can be placed through the angiocatheter and the tract dilated to allow percutaneous placement of a catheter for temporary drainage until the stoma can be surgically repaired.

If the stoma is wide open at the skin but the catheter hangs up inside before entering the pouch, this is usually caused by tortuosity of the limb or an outpouching just above the fascia rather than by a true stricture within the efferent limb. Changing catheters can often solve this problem. Straight red Robinson catheters are the least expensive and the easiest for patients to find at medical supply shops. However, coudé-tip catheters or stiffer catheters (e.g., those made by Coloplast Corp., Minneapolis) may be more successful for negotiating a tortuous efferent limb or overcoming a lip at the fascia. The patient should try several different catheters to see which one works most easily. Sometimes patient position affects the ease of passing the catheter; however, because it is not practical for the patient to catheterize only lying down every effort should be made to find a solution that works with the patient in the seated or standing position.

If changing catheters does not resolve the problem, then open surgical revision is required. We usually take down the entire stoma, mobilize the pouch through the old midline incision, resect excess length of the efferent limb, and reconstruct the stoma. This surgical procedure is significant and one should ensure that all other aspects of the diversion (e.g., continence mechanism, ureteral anastomoses) are working properly or can be repaired at the same time. The surgeon should be prepared for the possible need to cut a new segment of bowel to construct an entirely new efferent continence mechanism.

Complete reconstruction of the continence mechanism may require several different techniques and should be performed by a surgeon with wide experience in continent diversion. Useful techniques include using a tapered ileal segment tunneled into a new tinea of a right colon pouch by a Mitrofanoff technique or construction of an ileal patch with a tapered extraserosal tunnel using the T-pouch technique.[15] Both these mechanisms can be added to a mature right colon reservoir after the old nonfunctioning efferent limb is excised. If the pouch was originally made from ileum, a new T-limb efferent limb can be constructed using a new short segment of ileum.

CONVERSION FROM A CONTINENT TO A NONCONTINENT DIVERSION

Very rarely, the patient and surgeon decide that the best management of a problematic continent diversion is to convert it to a continuously draining conduit. Unfortunately, this is not a simple undertaking and can be more complex than fixing the continent diversion. It is unsatisfactory simply to excise the efferent continence mechanism and connect the pouch itself to the skin because this mechanism tends to make a poor stoma, has a high risk of herniation or prolapse, and empties poorly. If an afferent limb is present (e.g., with a Studer pouch or a right colon pouch with the ureters implanted into the distal ileal segment) then the reservoir may be discarded and the afferent limb brought up as an ileal stoma. Care must be taken not to compromise the blood supply to this segment when the rest of the reservoir is excised. In the absence of an afferent limb (e.g., with an Indiana pouch), it is best to discard the pouch and construct an ileal conduit from a new segment of ileum.

AFFERENT ANTIREFLUX MECHANISM

The need to provide an antireflux mechanism is controversial because of the very high rate of bacterial colonization in these reservoirs.[6] Commonly used antireflux mechanisms include the Kock intussuscepted nipple valve, tunneled ureteral anastomoses, the ileocecal valve, or an extraserosal tunnel (T-pouch). However, these mechanisms (with the exception of the ileocecal valve) have a significant risk of late upper tract obstruction because of stenosis of the antireflux valve or ureteral stricture, and good results have been reported with direct refluxing anastomosis.[16,36]

The Kock pouch used an intussuscepted ileal nipple valve that is a very effective antireflux mechanism. Initially, few

problems were related to this mechanism other than occasional stones on the surgical staples used to maintain the nipple valve. However, with long-term follow-up investigators discovered that late stenosis of the nipple valve was common, sometimes occurring 10 years or more after construction of the reservoir.[57] This problem can remain silent until the development of significant bilateral hydroureteronephrosis or even renal failure. The diagnosis is made on antegrade study, which depicts a dilated afferent limb and delayed emptying into the reservoir. Endoscopically, these stenotic nipple valves look white and scarred, with only a pinpoint opening that may require intravenous methylene blue to identify. Treatment involves intubation with an angled catheter and wire and then incision with a hot knife through the stenotic nipple until free drainage of the afferent limb is accomplished. A balloon incision device can also be used under careful direct vision. The main risk of this procedure is bleeding from the cut edge, which can be avoided by pinpoint coagulation. Incision of the valve is usually very effective in resolving the obstruction, although recurrent obstruction can occasionally develop. Most patients who undergo incision of the valve mechanism experience reflux that does not usually cause problems, likely due to the high-volume, low-pressure mature reservoir.

The T-pouch extraserosal tunnel mechanism was designed in part to address this risk of late stenosis in the Kock pouch by better maintaining an adequate blood supply to the afferent limb.[58] Stenosis is still occasionally observed, especially in patients who were previously irradiated or in whom the distal afferent limb was tapered during construction. Because of this risk, some no longer taper the limb before closing the tunnel over the top of the afferent limb.[59] The absolute risk of late stenosis will not be known until more patients have experienced long-term follow-up. Management is with endoscopic incision, similar to that described earlier for the Kock pouch.

We have also seen occasional afferent limb stenosis that appears to result from fibrosis of the midpoint of the ileal segment itself rather than the nipple valve (Fig. 46.7). These cases closely resemble the late fibrosis and lack of peristalsis seen with very long-term follow-up of ileal conduits.[60,61] As more patients live for many years with these continent diversions, we may find that this problem is more common than currently observed. Management requires replacement of the entire afferent limb with a new segment.

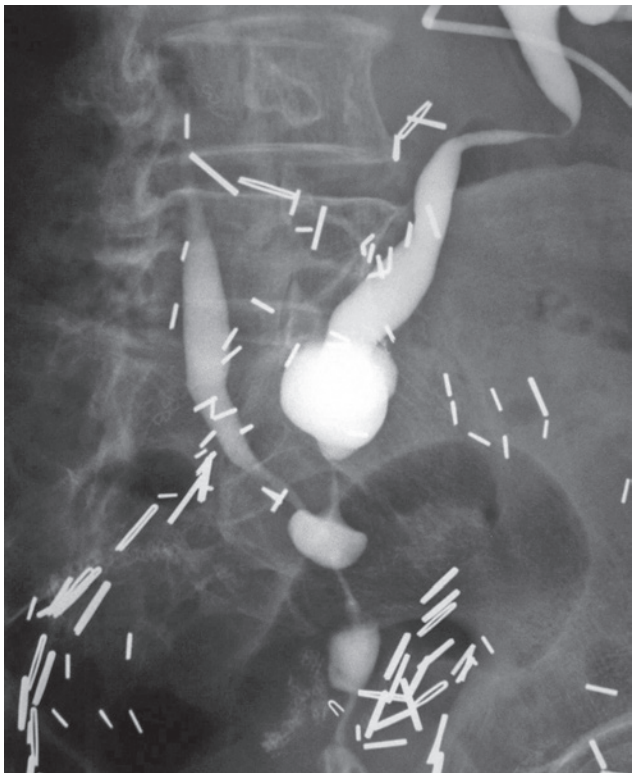


Figure 46.7 Stenosis of the midportion of the afferent limb in a patient with an ileal orthotopic neobladder. The diversion was 11 years old at the time of this diagnosis.

ACUTE POUCH RUPTURE

Spontaneous rupture of a cutaneous continent reservoir appears to be quite rare, although the exact incidence is unknown.[6,62] Mansson and colleagues polled surgeons who performed continent diversion in Scandinavia and reported that 17 patients out of a total of 1070 with cutaneous diversion suffered a spontaneous rupture, for an incidence of 1.6%.[63] Early rupture can very rarely occur in the first few postoperative weeks in a patient who is noncompliant with catheterization. Late rupture does not always have any obvious inciting event and seems to be more likely in patients who have been previously irradiated.

At presentation, the patient generally has acute severe abdominal pain and distention. Attempts to catheterize the pouch may return little urine. Unfortunately, delay in diagnosis is the rule and deaths have occurred in this situation as a result of abdominal sepsis. The diagnosis may be made on cystogram, although false-negative cystograms have been reported.[39] A CT cystogram may be more helpful. Rupture should be suspected in any patient with acute abdominal pain and ascites fluid seen on CT scan, even if actual extravasation is not demonstrated. Surgical repair is generally recommended, especially because the urine in these reservoirs is nearly always colonized with bacteria.

PARASTOMAL HERNIA

Parastomal hernias have been reported in approximately 4% of patients with continent cutaneous diversions, although the incidence may increase in patients with longer follow-up.[64] These hernias can appear with stomas at any location and are more commonly seen in patients who are elderly, obese, or smokers. These high-risk patients often also have ventral midline hernias from the abdominal incision. The parastomal hernia may lead to difficulty with catheterizing or incontinence. Repair when necessary may be attempted with a semicircle of permanent mesh placed around the stoma at the fascia level. This procedure is relatively simple for the patient because it does not require full laparotomy or adhesiolysis. Alternatively, the hernia may be repaired laparoscopically. In either approach, care must be taken to avoid placing the mesh directly against the wall of the efferent limb because that may lead to subsequent erosion of the mesh. Unfortunately, recurrence after these types of repair is not uncommon. The most secure repair



Figure 46.8 CT cystogram depicts no evidence of a urinary leak or fistula.

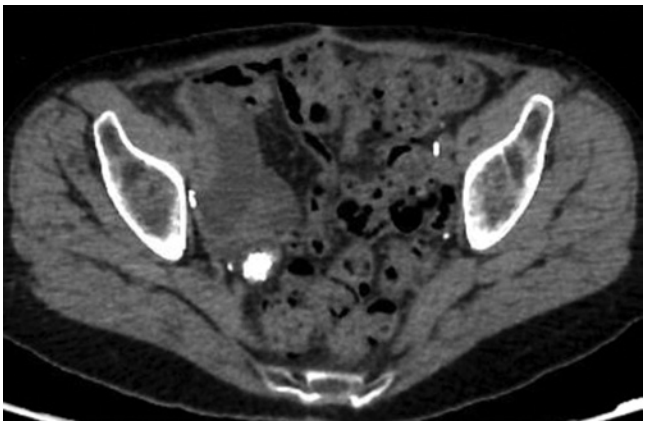


Figure 46.9 CT with a 1.5-cm stone in the pouch.

involves moving the stoma to a new site, a maneuver that requires open laparotomy and complete mobilization of the pouch. This major undertaking may occasionally require construction of an entirely new efferent limb.

LATE MALIGNANT DISEASES

The development of late malignant diseases in ureterosigmoidostomy diversions with a mean latency of 25 years was one of the factors leading to the virtual abandonment of this procedure in the United States. However, late malignant diseases have also been reported in nearly every other type of diversion, both ileal conduit and continent diversions using ileum and colon. The risk of such malignancy is unknown, but it appears to be very low.[65] The primary reason is that most patients undergoing cystectomy and continent diversion today are elderly, have invasive bladder cancer, and have a limited life expectancy.

Late adenocarcinomas have been reported in patients with continent colonic reservoirs, but with much shorter latency than that seen with ureterosigmoidostomy diversion.[65,66] Because the colon is already predisposed to develop benign and malignant polyps, it seems likely that these tumors may have existed before construction of the diversion (Figs. 46.8 and 46.9).

Conclusions

Continent cutaneous urinary diversion offers a reasonable alternative to ileal conduit or continent neobladder in properly selected patients. These operations are technically challenging, and postoperative complications are common. The surgeon undertaking continent cutaneous diversions must have a good understanding of the pathophysiology of these operations and be familiar with the diagnosis and management of their complications.

References

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Chapter 46 Questions

1. A 75-year-old woman with a history of interstitial cystitis and functioning right colon pouch with an appendix stoma to the umbilicus has persistent infected urine despite multiple courses of oral antibiotics. She catheterizes 5 times daily. She does not have fevers but complains of some pain over the pouch and very foul-smelling urine. Renal ultrasound 6 months earlier showed no hydronephrosis. What is the next management step?
   a. Increase frequency of catheterization
   b. Long-term intravenous antibiotics
   c. Conversion to an ileal conduit
   d. Non-contrast CT scan
   e. Daily low-dose antibiotic suppression

2. Stomal stenosis at the level of the skin is most common in which of the following?
   a. Indiana pouch
   b. Right colon pouch with appendix catheterizable stoma
   c. Right colon pouch with tubularized ileal stoma
   d. Cutaneous T-pouch
   e. Kock pouch

3. A 69-year-old man with a right colon pouch and tubularized ileal stoma has increasing difficulty with self-catheterization. On examination, he has a stenotic stoma with built-up white scar tissue around the stoma edge. You are unable to pass a 14-F straight catheter. What is the next step?
   a. Gently dilate the stoma with female sounds and leave a 16-Fr catheter in the stoma taped in for a few days
   b. Flexible cystoscopy
   c. Bilateral percutaneous nephrostomy tubes
   e. Y-V plasty of the stoma
   d. Formal stoma revision for moving the stoma to another site

4. What is management of stomal stenosis at the skin with best long-term results?
   a. Office dilation with female urethral sounds
   b. Placement of a stoma catheter to facilitate passive dilation of the skin
   c. Office incision of the stenotic skin edge
   d. Y-V plasty of the stoma
   e. Formal stoma revision

5. A 65 year-old patient with history of stenosis at the skin requiring stomal dilation in clinic wakes up from significant abdominal discomfort. She cannot catheterize her stoma. By the time she sees you, she is in intense pain from the distended pouch. Catheterization with different sized Coudé-tip catheters as well as attempts at passage of a wire via flexible endoscopy are unsuccessful. What is the next step in management?
   a. Give narcotics, and come back to try again in 1 hour
   b. Placement of bilateral nephrostomy tubes
   c. Percutaneously drainage of the pouch
   d. Emergency revision of the stoma in the operating room
   e. Transfer to a tertiary care center with a surgeon experienced in cutaneous diversions

6. A 72-year-old male with radical cystectomy and right colon pouch with tubularized ileal stoma for muscle invasive bladder cancer 2 years ago comes in for annual evaluation. He has had no difficulty with pouch catheterizations, which he performs at least 5 times daily. He brings in a recent pouch urine culture collected by his primary care provider that reports 100,000 CFU/ml Escherichia coli that is pan-sensitive. He is worried that he has a urinary infection and asks about treatment. He reports no fevers and no pain, and says that his only complaint over the past few months has been foul-smelling urine on a rare occasion. Labs reveal no leukocytosis and serum Cr 1.1 mg/dL that is at baseline. A CT scan obtained earlier today depicted no evidence of kidney or pouch stones, no evidence of recurrent malignancy, and no evidence of upper tract obstruction on renal delayed phase images. What is the next step in management?
   a. 3-day course of fluoroquinolone antibiotic and teach patient daily pouch irrigation with saline solution
   b. 3-day course of fluoroquinolone antibiotic followed by prophylactic antibiotics
   c. Cystoscopy of the efferent limb and pouch in the office
   d. Cystogram of the pouch
   e. Observation

7. A patient with a history of kidney stones and an extraserosal tunnel (T-pouch) continent cutaneous diversion comes in 4 months following his surgery complaining of persistent small volume urine leakage, despite self-catheterization of the pouch at least 5 to 6 times daily. He has no fevers and no pain over the area of the pouch. What is the next step in management?
   a. Observe the patient self-catheterize
   b. Endoscopy of the pouch
   c. Cystogram of the pouch with drainage views
   d. Urodynamics to evaluate to evaluate for high-pressure contractions within the pouch
   e. CT scan to assess for pouch or kidney stones

8. A 67-year-old woman develops fecal material in the urinary drainage bag 2 weeks following cutaneous diversion with a right colon pouch. She has no associated fever and no pain. A CT scan with oral and intravenous contrast depicts no evidence of an intra-abdominal abscess, with a clearly defined fistula between the bowel anastomosis and the reservoir. What is the next step in management?
   a. Cystogram of the pouch with drainage views to better delineate the location of the fistula
   b. Endoscopy of the pouch to evaluate the size of the fistula
   c. Bilateral nephrostomy tubes to divert the urinary stream from the fistula
   d. Surgical exploration and fistula repair for definitive treatment
   e. Bowel rest and parenteral nutrition supplementation

Q9–10. A 68-year-old man has a cystectomy and continent cutaneous diversion with an ileal T pouch, constructed with afferent and efferent tapered ileum with extraserosal tunnels. He is continent and has no trouble catheterizing his stoma. Four years later his serum creatinine level has increased from a baseline of 1.1 to 1.4 mg/dL. His CT scan depicts moderate new onset bilateral hydroureteronephrosis.

9. What is the next step in management?
   a. Increase the frequency of catheterization
   b. Irrigate the pouch daily
   c. Place a permanent catheter in the stoma
   d. Place bilateral percutaneous nephrostomy tubes
   e. Perform endoscopy of the pouch

10. Endoscopy is performed with a flexible cystoscope. Following intravenous administration of methylene blue, the pinpoint sized afferent opening is catheterized with an angled catheter and wire. Retrograde pyelogram depicts bilateral hydroureteronephrosis (more severe on the left) with delayed emptying into the reservoir. What is the next management step?
    a. Placement of a ureteral stent for 6 weeks
    b. Incision of the afferent valve
    c. Left to right transureteroureterostomy
    d. Open excision of the afferent valve and reimplantation of the ureters into the pouch
    e. Conversion to an ileal conduit

11. A 59-year-old woman a continent cutaneous diversion with a right colon pouch has gross hematuria, abdominal pain, and leakage of urine in between catheterizations. A non-contrast CT scan depicts a 5 mm stone in her pouch with no associated kidney stones. How should this stone be managed?
    a. Urinary alkalinization and observation for the stone to pass
    b. Shock wave lithotripsy
    c. Endoscopic removal through the stoma with a flexible cystoscope and holmium laser
    d. Percutaneous extraction through a puncture between the stoma and the perioperative percutaneous catheter drain
    e. Open surgical extraction of the stones

Case Studies

CASE 1

A 71-year-old woman is diagnosed with a large muscle invasive bladder tumor causing right hydronephrosis. Following neoadjuvant chemotherapy, she is noted to have a partial response by CT scan and undergoes definitive management with a radical cystectomy anterior exenteration continent cutaneous urinary diversion with a right colon pouch and appendix catheterizable stoma. She develops stomal stenosis of the skin 7 months later and is having an increasingly difficult time catheterizing through the stoma. Attempted dilation in clinic with female urethral sounds did not result in improvement with catheterizations. Serum Cr is 1.3 mg/dL, slightly increased from a baseline of 1.0 mg/dL. CT scan depicts no evidence of hydronephrosis or urolithiasis.



Case Figure 46.1

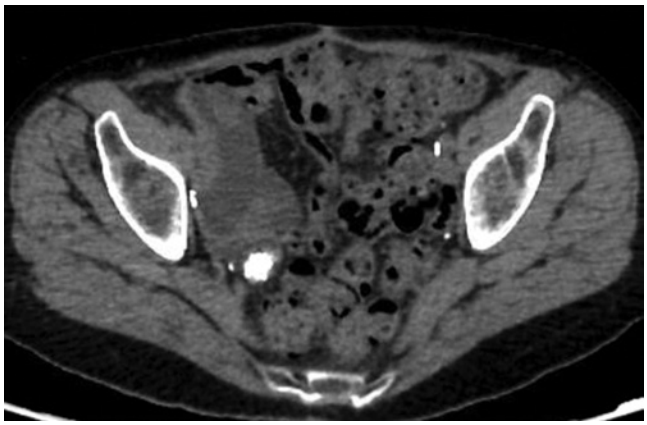
1. What is the next step in management?
   a. Flexible cystoscopy
   b. Percutaneous drainage of the pouch
   c. Bilateral percutaneous nephrostomy tubes
   d. Y-V plasty of the stoma
   e. Formal stoma revision

2. She undergoes Y-V plasty of the stoma and is subsequently able to catheterize without difficulty; however 2 years later she develops progressively worsening urinary leakage in between catheterizations, especially when she is ambulatory. In clinic you observe that she catheterizes with ease and correctly pinches the catheter on withdrawal to avoid backflow of urine. Endoscopy of the pouch is normal and a cystogram with drainage views is shown in Case Fig. 46.1. The next step is:
   a. Observation
   b. Leave a catheter in the pouch for a few days
   c. Urodynamics to evaluate for high-pressure contractions within the pouch
   d. Repeat endoscopy of the pouch in 3 months
   e. Formal stoma revision

3. Filling urodynamics show peak pressure waves of 20 cm water. CT scan shows no hydronephrosis and no urolithiasis. The next step is:
   a. Increased frequency of catheterizations
   b. Leave a catheter in the pouch for a few days
   c. Augmentation of the reservoir with a patch of ileum
   d. Open repair or replacement of the efferent catheterizable continence limb
   e. Conversion to an ileal conduit

CASE 2

A 72-year-old woman with history of anterior pelvic exenteration and construction of an Indiana pouch 4 years ago for high-grade noninvasive bladder cancer presents



Case Figure 46.2

to you with recurrent pain over the pouch for the last 6 months associated with persistently infected urine. She has a known blown-out, nonfunctioning left kidney from a prior ureteral stricture. Her pain resolves with culture-tailored oral antibiotics, but recurs off antibiotics. She self-catheterizes four to six times per day without difficulty. Surveillance with MRI 3 months ago showed no evidence of disease recurrence, no right hydronephrosis, and the known left hydronephrosis.

1. What is the next step in management?
   a. Urodynamics
   b. Daily low-dose antibiotics
   c. Noncontrast CT scan
   d. Increase frequency of catheterization
   e. Left percutaneous nephrostomy tube

2. CT scan of the pouch is shown in Case Fig. 46.2. The pouch stone is 1.5 cm in size. There are no kidney stones. How should this stone be managed?
   a. Dissolution therapy with urinary alkalinization
   b. Endoscopic treatment with a flexible cystoscope and holmium laser
   c. Shock wave lithotripsy
   d. Percutaneous ultrasound-guided stone extraction
   e. Open surgical extraction of the stones

3. The patient undergoes endoscopic laser lithotripsy of the pouch stone. She is lost to follow-up and returns 4 years later with an x-ray of the abdomen that depicts two 5-cm stones in the pouch. What is the best management of these stones?
   a. Dissolution therapy with urinary alkalinization
   b. Endoscopic treatment with a flexible cystoscope and holmium laser
   c. Shock wave lithotripsy
   d. Percutaneous ultrasound-guided stone extraction
   e. Open surgical extraction of the stones

Answers

1. **d.** Patients with cutaneous diversion who have persistent urinary infections should be evaluated for completeness of emptying, hydronephrosis, and the presence of stones in the pouch or in the kidney that represent a nidus for persistence of the urinary pathogen. Stones are almost always radiopaque and are best identified on a noncontrast CT scan.
2. **b.** Stomal stenosis at the level of the skin is particularly common when the appendix is used for the efferent limb, presumably in part due to compromised blood supply at the appendix tip. Stomal stenosis can be minimized by making a V-shaped flap when opening the skin and dropping the skin flap into the spatulated antimesenteric side of the efferent limb when it is matured to the skin. This maneuver can be performed whether the stoma is in the right lower quadrant or at the umbilicus.
3. **a.** The initial step in management of stomal stenosis at the level of the skin is office dilation with sounds and placement of a catheter in the stoma for additional passive dilation. If this does not improve self-catheterization, subsequent steps are office excision of the scar tissue or surgical repair with outpatient Y-V plasty of the stoma or formal revision of the stoma.
4. **e.** All of the choices are steps in the management of stomal stenosis at the level of the skin; however, formal revision of the stoma is the most successful in difficult cases and has the best long-term results. The efferent limb (appendix or ileum) is mobilized down to the fascia, the old mucocutaneous border excised, and a freshly spatulated stoma constructed with an interposed flap of skin.
5. **c.** Complete inability to catheterize despite multiple attempts is an emergency. If initial attempts at access of the pouch are unsuccessful, the overdistended pouch should be drained percutaneously to relieve the patient's pain. The procedure can be done safely percutaneously with a long 18-gauge or 16-gauge angiocatheter. If the location of the pouch is unclear, a test pass can be made with a fine spinal needle or bedside ultrasound guidance should be utilized.
6. **e.** This patient has asymptomatic bacterial colonization of the pouch, which is essentially universal in patients with a continent cutaneous reservoir on intermittent catheterization. It is very important not to subject patients to unnecessary antibiotics for asymptomatic bacterial colonization. Patients and their primary care physicians need to be instructed in this principle.
7. **a.** Persistent incontinence from cutaneous continent reservoirs affects an average 15% of patients and usually requires surgical repair. However, on occasion what is interpreted as urine leakage is actually mucus drainage from the efferent limb (which is unavoidable) or a small amount of urine left in the efferent limb after failure to pinch the catheter on withdrawal. Thus, an important initial step prior to proceeding with a diagnostic approach for anticipated surgical correction is to observe the patient catheterizing to determine if this is done correctly.
8. **e.** A fistula to the pouch is generally caused by a leak from the bowel anastomosis or a missed bowel injury. In this patient, it is most likely due to a leak from the bowel anastomosis given its proximity to the pouch. The recommended management is bowel rest with parenteral nutrition. Early surgical exploration is difficult in the setting of inflammatory postoperative reaction and should be avoided in favor of delayed repeat

exploration and repair if the fistula does not resolve within 4 to 6 weeks of bowel rest.

9. **e.** The most likely cause of bilateral hydronephrosis in this setting is stenosis of the afferent limb where it inserts into the pouch. This is easily identified on endoscopy which will show a pinpoint opening where the afferent limb empties into the pouch.
10. **b.** The Kock pouch used an intussuscepted ileal nipple valve as a very effective antireflux mechanism. Although there were few early complications related to this mechanism (occasional stones on the surgical staples used to maintain the nipple valve), a notable late complication was stenosis of the nipple valve. This problem can potentially remain silent until the development of significant bilateral hydroureteronephrosis or renal injury. The first step in management is endoscopic evaluation of the pouch – the stenotic nipple valve appears white and scarred, its pinpoint opening usually requiring intravenous methylene blue for identification. Treatment involves intubation of the opening with an angled catheter and wire followed by incision of the afferent valve with a hot knife through the stenotic nipple until free drainage of the afferent limb is accomplished. This is usually very effective in resolving the obstruction, and open surgical revision is rarely required.
11. **c.** Pouch stones should not be observed because they are unlikely to pass via the efferent limb and inevitably increase in size as more stone deposits in layers. The recommended treatment is complete removal at the time of initial diagnosis, which for a stone this size can be efficiently performed with laser lithotripsy and stone basketing via a flexible cystoscope. Extracorporeal shock wave lithotripsy is not recommended for pouch stones because of the need to remove all fragments to prevent recurrence. Open surgical repair is reserved for pouch stones larger than 3–4 cm in diameter.

CASE 1

1. **b.** A patient with acute inability to drain a continent cutaneous reservoir is often in acute pain by the time of treatment. If simple dilation of the stoma or negotiation of a smaller catheter is not possible, draining the pouch percutaneously can often relieve pressure and allow time to negotiate a catheter in. If an angiocatheter is used a wire could be passed and used to place a temporary suprapubic catheter if necessary.
2. **c.** The cystogram shown depicts no evidence of urinary leak or urinary fistula. On the basis of the diagnostic evaluation, this patient has urinary incontinence. Incontinence in a diversion with an appendix catheterizable stoma is infrequent but usually requires surgical repair. It may be due to loss of the reinforced tunnel at the base of the appendix or erosion of the appendix from an indwelling catheter. Prior to surgical management, urodynamic studies to identify high-pressure contractions are helpful in defining the problem and to delineate the type of surgical repair.
3. **d.** Augmentation of the reservoir is not indicated in the setting of low-pressure contractions within the pouch. However as persistent leakage is due to a failure of the continence mechanism, increased frequency of catheterizations or an indwelling catheter are insufficient and formal stoma revision is required. Surgical repair consists of either making a new tunnel at the base of the appendix using the Mitrofanoff principle or constructing an entirely new efferent limb with a tapered ileal segment (see Case Fig. 46.1).

CASE 2

1. **c.** Patients with cutaneous diversion and persistent infections should be evaluated for the presence of pouch or kidney stones. Stones are not well seen on MRI and are best identified with a noncontrast CT scan.
2. **b.** Pouch stones are unlikely to dissolve or pass. The recommended treatment is complete removal at the time of initial diagnosis. This stone is small enough to be efficiently treated with laser lithotripsy and stone basketing via a flexible cystoscope. Extracorporeal shock wave lithotripsy is not recommended for pouch stones because of the need to remove all fragments to prevent recurrence. Percutaneous management is reserved for larger stones or stones in a difficult location within the pouch.
3. **e.** When patients with continent cutaneous diversion are not followed up with at least annual radiographs, they may present with very large stones in the pouch. Endoscopic or percutaneous management is inefficient for stones that are larger than 3–4 cm in diameter. The best management is a simple open cystotomy lateral and superior to the stoma (see Case Fig. 46.2).

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47 Complications of Orthotopic Neobladder

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CHAPTER OUTLINE

Patient Selection and Contraindications to Orthotopic Diversion
Surgical Complications
Bowel Complications
Urethral Anastomotic Complications
Ureterointestinal Anastomotic Complications
Urolithiasis
Urinary Tract Colonization and Pyelonephritis
Fistulas
Voiding Dysfunction
Urethral and Pelvic Tumor Recurrence
Neobladder Rupture
Chapter 47 Questions and Answers

KEY POINTS

1. Proper patient selection is probably the single most important factor in determining the ultimate success or failure of orthotopic neobladder diversion.
2. Absolute contraindications to orthotopic neobladder include significant renal disease, severe hepatic dysfunction, inflammatory bowel disease, radiation enteritis, sphincter dysfunction, severe urethral stricture disease, inability to manage neobladder care, and any compromise of oncologic control.
3. Most neovesical-urethral anastomotic leaks will spontaneously close with conservative management; however, it is critical to evaluate for outlet obstruction due to mucus retention to prevent neobladder perforation.
4. Ureterointestinal strictures are less prevalent with a refluxing anastomosis. Such strictures are optimally approached in an antegrade fashion for initial endoscopic management and will likely require surgical correction.
5. Patient counseling about potential neobladder voiding dysfunction including nighttime incontinence, stress incontinence, and hypercontinence must be thoroughly addressed preoperatively so that functional outcomes are aligned with patient expectations.

Since the 19th century, urologists have used intestinal segments for reconstruction of the urinary tract following extirpative surgical procedures. However, objectives have evolved from a simple diversion of urine with preservation of renal function to the anatomic and functional preservation of volitional voiding without altered body image. In fact, the desire to afford patients with a near-normal state of voiding by preserving the natural continence mechanism while eliminating a cutaneous stoma or absolute requirement for intermittent catheterization led to the development of orthotopic urinary diversion. Orthotopic bladder substitution, first pioneered by Lemoine[1] in the early 20th century and popularized by Camey and LeDuc,[2] has been extensively refined[3–6] to a procedure with excellent patient satisfaction and acceptably low morbidity.

Many techniques exist for creation of an orthotopic neobladder.[7–12] Ileum is the bowel segment of choice because of ease of construction, lower storage pressures, less urine absorption, and lower mucus production as compared with large bowel. The most commonly performed ileal reservoirs fall into one of two types: the U-shaped ileal neobladder as described by Studer and associates[13] and the W-shaped reservoir that was initially described by Hautmann and colleagues.[3,10] Basic requirements for an acceptable orthotopic urinary neobladder include a capacious, low-pressure reservoir that provides acceptable continence without compromising cancer control. Both the Studer and Hautmann configurations are easily constructed using an afferent limb or chimney that facilitates the ureteroileal anastomosis.

As contemporary surgeons have become more familiar and dexterous with robotic surgery, robotic radical cystectomy has increased in utilization. While the cystectomy portion is generally performed intracorporally, many surgeons are reluctant to perform the urinary diversion intracorporally due to the technical challenges and increased operative times required. Intracorporeal robotic neobladder diversion techniques have been refined and are typically performed using a modified Studer technique,[14] and their frequency will increase over time.

Multiple large published series and reviews have reported the surgical complications and long-term outcomes of open orthotopic neobladders.[15–17] Robotic intracorporeal

neobladder diversion has been shown to have similar complication rates to that of open series.[18] Randomized studies comparing open and robotic neobladder diversions have yet to be performed and may ultimately answer if the robotic technique offers an advantage over open techniques. Most potential complications, including the diagnosis and treatment options outlined in this chapter, are generally applicable to all methods of orthotopic neobladder diversion. As discussed in further detail, typical early postoperative complications are similar to those seen with other types of urinary diversion and can include persistent urine leak, pyelonephritis, and bowel complications such as ileus and small bowel obstruction. Late complications can include ureteroenteric and neovesical-urethral anastomotic stricture, urinary fistula, and urolithiasis. Additionally, the issues and complications unique to orthotopic neobladder, including patient selection concerns, voiding dysfunction, and incontinence, are addressed.

Patient Selection and Contraindications to Orthotopic Diversion

Fortunately, we practice urology in an era when bladder cancer has become a survivable disease for a substantial percentage of patients and the long-term outlook is a component of the algorithm for the consideration of treatment options. With improvements in anesthesia and surgical technique, radical cystectomy is feasible even in patients of advanced age and with significant comorbid conditions.[19–21] In choosing to perform an orthotopic neobladder, proper patient selection is probably the single most important factor in determining the ultimate success or failure of the procedure. Patients must be cognizant of the medical, physical, and emotional demands of a continent urinary reservoir, must be highly motivated and capable of performing self-catheterization, and must be compliant with the necessary follow-up regimen.[12] Thus, patients with severe mental impairment should not undergo orthotopic diversion.

Preoperative counseling on methods of urinary diversion by a trained wound ostomy continence nurse can aid immensely in both the physical and mental preparations of the patient for the demands of a neobladder and should be obtained for all patients regardless of choice of diversion. The wound ostomy continence nurse should mark the patient for an appropriate stomal site on the abdominal wall in the event that intraoperative factors preclude neobladder diversion and noncontinent diversion is performed.

Although some risk factors that were previously considered contraindications to neobladder, including advanced age, have changed with improved technique,[16] absolute contraindications to creation of an orthotopic reservoir still exist (Table 47.1). Sound oncologic principles should always supersede the preference of diversion, most prominently the achievement of negative surgical margins at the site of the neoanastomosis. In women, orthotopic diversion should be reserved for patients whose tumors do not involve the bladder neck or urethra. In men, involvement of the prostatic stroma or apex is an absolute contraindication to neobladder diversion. Investigators have strongly recommended that frozen section analysis of urethral margins be performed intraoperatively before construction of an orthotopic diversion.[22] Orthotopic reconstruction is absolutely contraindicated in patients in whom simultaneous urethrectomy is indicated on the basis of their primary tumor.

Table 47.1 Absolute Contraindications to Orthotopic Neobladder

Medical	Oncologic
Compromised renal function	Bladder neck involvement: female patient
Serum creatinine >2.0 mg/dL or creatinine clearance <60 mL/min	Prostatic urethral or apical involvement: male patient
Severe hepatic dysfunction	Need for simultaneous urethrectomy
Compromised intestinal function	Failure to achieve negative urethral margin
Inflammatory bowel disease	
Radiation enteritis	
External sphincter dysfunction	
Severe urethral stricture disease	
Severe mental impairment	

Significant benign urethral disease such as profound stricture is also considered an absolute contraindication. Furthermore, patients with external sphincter dysfunction, a severely compromised rhabdosphincter, or an incompetent urethra should also be excluded from placement of a neobladder. In addition, severe acute or chronic inflammatory bowel disease affecting the chosen bowel segment is a contraindication to construction of a neobladder.[23] In general, continent urinary diversion should not be performed in patients with significant renal or hepatic impairment.[24–26] Isolated case reports have advocated the use of continent urinary diversions in select patients with renal insufficiency.[27,28] However, the prolonged metabolic acidosis associated with neobladder diversion is generally poorly tolerated in patients with any degree of renal compromise.[29] In most adult patients, neobladder diversion should be performed only if the serum creatinine concentration is <2 mg/dL.[30]

Patients considered for continent diversion should have normal liver function because reabsorption of ammonium and chloride can worsen hepatic impairment and can precipitate encephalopathy.[24,31] Some surgeons consider stress urinary incontinence an absolute contraindication for neobladder diversion.[16] However, as discussed later, techniques for management of stress incontinence in patients with neobladders are increasingly acknowledged.

As mentioned earlier, several factors previously considered inadvisable to selection of patients for orthotopic diversion, such as obesity, advanced chronologic age, prior abdominal surgical procedures, or the presence of metastases in pelvic lymph nodes, when taken individually are no longer considered absolute contraindications.[12,32,33] Indeed, management of bladder cancer in the elderly patient is becoming an increasingly important issue as the general population ages. Clark and colleagues[19] demonstrated that radical cystectomy with orthotopic urinary diversion could be performed even in persons of significantly advanced age without escalating operative mortality or diversion-related complications.

Although patients with increased body mass index have been shown to have higher rates of transfusion[34] and of postoperative complications,[35] investigators generally accept that weight per se does not affect cancer-specific survival

and is not an absolute contraindication for performing cystectomy with continent diversion.[36] Neobladder may be a preferable diversion choice in severely obese patients where increased anterior abdominal adiposity makes it difficult to create a low tension cutaneous stoma. In addition, avoidance of a cutaneous stoma in morbidly obese patients may preclude development of stomal complications including the development of a parastomal hernia. Multiple studies demonstrated that the incidence of local pelvic recurrence with lymph node–positive disease is approximately 11% and the presence of positive lymph nodes by itself should not preclude placement of an orthotopic diversion.[12,33] In patients who have received prior pelvic irradiation, great care must be taken to select a bowel segment out of the confines of the radiated field. Salvage cystectomy with neobladder diversion is a technically challenging procedure but has been demonstrated to be a viable option in selected cases.[21,37–39] However, patients should be preoperatively counseled on reported incontinence rates approaching 25% following salvage cystectomy with neobladder and the possible need for artificial urinary sphincter placement in the future.[12]

Surgical Complications

Proper patient preparation and adherence to meticulous surgical technique are paramount in the prevention of surgical complications. Although controversy existed in the current literature from urologic and colorectal surgery,[40] investigators previously accepted that urologic patients who have an intestinal procedure on unprepared bowel have an increased incidence of wound infections, intraperitoneal abscess formation, and bowel anastomotic leakage when compared with patients who have preoperative mechanical bowel preparation.[30,41] Various methods are employed for mechanical cleansing of the bowel.[42] Current protocols often administer large volumes of an oral polyethylene glycol solution. Not all patients readily tolerate this treatment because of the large amount of fluid that must be ingested, in addition to the nausea, emesis, and abdominal cramping that are frequent side effects of the bowel preparation. Elderly patients may be unable to complete this regimen as a result of these mentioned side effects in combination with dehydration induced by the profuse diarrhea. Thus, some patients may benefit from preoperative admission specifically for bowel preparation. Alternatively, oral sodium phosphate solutions can produce equivalent mechanical cleansing with the consumption of significantly less volume.[43,44] Recent evidence from colorectal and urology literature suggests that there is no increased risk of complications (superficial infections, fascial dehiscence, or anastomotic leakage) in patients not undergoing mechanical bowel preparation.[45] As a result, there has been a move away from preoperative mechanical bowel preparations in patients undergoing cystectomy and urinary diversion.[46,47] Antibiotic bowel preparations are often used in combination with mechanical cleansing and consist of timed doses of neomycin and erythromycin base or metronidazole on the day before the surgical procedure.[48,49] However, articles in the general surgery and colorectal literature have suggested that preoperative bowel preparation with oral antibiotics may be safely omitted in the current era of potent intravenous (IV) antibiotics.[50]

An advisory statement from the National Surgical Infection Prevention Project outlined the use of perioperative antibiotics for prevention of surgical site infections.[51] The working group endorsed infusion of the antimicrobial dose within 60 minutes of incision and suggested that antibiotic prophylaxis be discontinued within 24 hours after the operation. Although the committee did not specifically address urologic surgery, cephalosporins were included in the recommendations for general abdominal, colon, cardiac, orthopedic, gynecologic, and vascular surgical procedures. To decrease wound infection rates in bowel surgery, preoperative IV doses of a second- or third-generation cephalosporin such as cefoxitin, 2 g, should be administered within an hour of incision. For patients with allergies to β-lactam antibiotics, perioperative doses of vancomycin, 1 g IV, in conjunction with clindamycin, 600–900 mg IV, should be substituted. The American Urologic Association Best Practice Statement on Urologic Surgery Antimicrobial Prophylaxis recommends administration of a second- or third-generation cephalosporin or aminoglycoside + metronidazole or clindamycin as first-line prophylaxis.[52] Pariser et al. demonstrated a reduction in postoperative infection rates and subsequent morbidity by changing the perioperative antibiotic regimen prior to cystectomy from cefoxitin alone to vancomycin, gentamicin, and fluconazole based on analysis of prior positive culture data within 30 days of cystectomy during a 2-year time period.[53] Thus perioperative antibiotic regimens may be refined to reflect institutional and regional antibiotic resistance characteristics.

Venous thromboembolism has been recognized in approximately 1–6% of patients undergoing radical cystectomy with orthotopic diversion.[54–58] Studies have advocated the use of venous thromboembolism prophylaxis for major urologic surgical procoedures,[59–61] as underscored by the knowledge of a higher incidence of deep vein thrombosis in patients with cancer.[62] Low-molecular-weight heparin or alternatively low-dose unfractionated heparin should be administered preoperatively and during the length of hospitalization. Graduated compression stockings and intermittent pneumatic compression may be used in conjunction with systemic anticoagulation. Controversy exists concerning the optimal duration of thromboembolic therapy administered for deep vein thrombosis prophylaxis.[59] Continuation of anticoagulant therapy following hospital discharge is determined at the level of the individual patient with special consideration to the patient's history, age, and mobility.[63]

Intraoperatively, strict adherence to general principles such as preservation of intestinal blood supply, gentle handling of tissue, avoidance of spillage of enteric contents, careful orientation of bowel segments, and realignment of the mesentery is critical in the avoidance of bowel-related complications. Occasionally a patient has such significant bowel adhesions or a tethered mesentery that placement of the neobladder within the pelvis becomes unfeasible. Multiple maneuvers are available for attempts to place the neobladder to the proper anatomic location for urethral anastomosis,[10] but in the event these are unsuccessful, continent cutaneous diversion or incontinent diversion with an ileal conduit should be performed.

BOWEL COMPLICATIONS

Early bowel complications are usually related to the bowel resection and subsequent anastomosis. These complications can include anastomotic leak, enteric fistula, bowel obstruction, and prolonged ileus. These entities often manifest in the early postoperative period as wound infections or abdominal abscesses and if undiscovered may progress to sepsis. Fortunately, these complications are relatively uncommon but nonetheless may be a cause of early major morbidity and mortality. This possibility underscores the need for prompt recognition and treatment.

The most common cause of delay in bowel function following intestinal reconstruction is paralytic ileus.[64] The incidence of this complication varies by series, era, and definition but in general approaches 20%. In a series of 304 patients who underwent radical cystectomy, half of whom underwent neobladder diversions, ileus was the most common cause of increased length of hospital stay and was clinically apparent in 18% of patients.[57] Most of these cases resolved with conservative management. Conservative management entails early ambulation, correction of electrolyte abnormalities, and encouraging moderate use of narcotic pain medications. Nasogastric tubes were not used routinely in this cohort and were reserved only for those patients with significant abdominal distention or emesis. Other series also advocated avoidance of nasogastric tubes or their early removal following cystectomy and urinary diversion.[65–67]

Although published evidence is not overwhelming,[68,69] total parenteral nutrition should be considered in patients with prolonged delay in enteral feeding, to avoid subsequent clinical malnutrition and deterioration.[70] More recent series have indicated that early oral or parenteral feeding may not affect the return of bowel function,[71,72] so the use of oral or parenteral nutrition is possibly best reserved for patients with prolonged ileus. Patients who undergo cystectomy should also routinely be treated with a proton pump inhibitor or histamine (H_2) blocker to decrease gastric pH and to facilitate prevention of clinically significant gastric bleeding.[73] Although some surgeons favor the use of metoclopramide as an adjunct to prevent postoperative nausea and vomiting by promoting intestinal motility, no substantial evidence from controlled trials supports this approach.[74]

Bowel obstruction occurs uncommonly in the early postoperative setting, although the historical incidence is between 1% and 15%.[30,64,75] Patients with obstruction may experience any combination of abdominal pain, distention, nausea, emesis, and obstipation. Because mechanical ileus provokes dehydration and electrolyte disturbances, adequate fluid resuscitation, particularly replacement of nasogastric tube output, is critical.

Initial imaging traditionally included flat and upright plain abdominal films to demonstrate distended loops of bowel on the supine view (Fig. 47.1), as well as air-fluid levels on the upright view. An unresolving obstruction may merit imaging with computed tomography (CT) including oral contrast or an upper gastrointestinal series with a small-bowel follow-through to define the point of mechanical obstruction further. As with paralytic ileus, most partial, mechanical, bowel obstructions resolve with conservative management, and only a few patients require reoperation.[56,64,76,77] The most common causes of bowel obstruction



Figure 47.1 Partial small bowel obstruction in an abdominal plain film following cystectomy. Note the substantial dilation of the small bowel and limited air in the distal colon. This patient has a solitary kidney and thus a single ureteral stent emanating from the neobladder.

are adhesions, although fascial and internal hernias can be culpable as well. In addition to careful closure of mesenteric apertures, a novel bioabsorbable membrane of hyaluronate and carboxymethylcellulose (Seprafilm) is available for intraoperative application to diminish the rate of significant bowel adhesions.[78]

Recurrent cancer should always be considered in the differential diagnosis in patients presenting with a late bowel-related complication, even in the absence of demonstrable radiographic findings. When surgical exploration is required, tissue sampling should be obtained to rule out recurrent cancer.

Anastomotic bowel leak or breakdown is a potentially devastating complication that has been reported in urologic reconstruction in 1–5% of patients.[79] Factors contributing to anastomotic breakdown include surgical techniques, bowel ischemia, prior radiation therapy, systemic steroid use, inflammatory bowel disease, and distal bowel obstruction. Attempts to avoid anastomotic breakdown include adequate bowel preparation, irrigation of the bowel segment before manipulation to prevent undue spillage of enteric contents into the peritoneum, use of nonirradiated and well-vascularized bowel, and placement of omentum over the anastomosis.[30,79] Patients with poor nutritional status or chronic pulmonary disease and those who received >2 U red blood cell transfusions also appear to be at higher risk for anastomotic complications.[80]

Unrecognized anastomotic leaks may lead to septic complications including abscess formation, wound dehiscence, and fistula formation. This possibility underscores the importance of early recognition and prompt correction. Fever, leukocytosis, and abdominal pain in the early postoperative period should be aggressively evaluated with abdominal CT scan with oral and IV contrast to delineate the anastomotic leak and any developing abscess. Broad-spectrum

antibiotics should be administered early to prevent the development of sepsis, and patients should be kept without oral intake. Although on many occasions the abscess can be percutaneously drained by interventional radiologic means, the surgeon must maintain a high level of vigilance and suspicion for the potential presence of necrotic bowel, which would require emergency reoperation.[79]

Resection of >60 cm of ileum for neobladder formation may decrease bile acid reabsorption that cannot be adequately compensated for by hepatic production, with resulting bile salt, lipid, and vitamin B_{12} malabsorption and profound diarrhea.[81] Oxalate levels may additionally become elevated and thus increase the propensity for urinary calculus formation. Cholestyramine has been used to bind excess bile acids and to treat diarrhea, but long-term therapy is poorly tolerated.[82,83] Careful attention to preservation of the ileocecal valve and appropriate use of <60 cm of intestine are the best strategies to prevent sequelae of malabsorption.

Orthotopic diversion allows significant prolonged contact of urine with bowel mucosa. When ileum is used for neobladder construction, ammonium, hydrogen ion, and chloride are reabsorbed with wasting of sodium and bicarbonate into the lumen and resulting hyperchloremic metabolic acidosis, which is reported to occur in ≤10% of patients.[24,84] Early postoperative treatment with sodium bicarbonate (2–6 g/day) may assist in preventing the salt-wasting hypovolemic and acidotic state.[16] Patients are usually weaned from these treatments after the first few months because persistent significant acidosis is rare in patients with normal renal function. However, yearly monitoring of electrolyte status can diagnose and help avert long-term complications of acidosis, such as bone demineralization.

URETHRAL ANASTOMOTIC COMPLICATIONS

The ileal neobladder can be complicated by persistent urinary leakage at the neovesical-urethral anastomosis, as manifested by high drain output in the postoperative period. Large series specifically addressing neobladder diversion indicated early urethral anastomotic leak occurrence of between 2.1% and 6.6%, with later ileourethral leakage at <1%.[16] Additional series reported rates of urethral anastomotic leak of approximately 3–7.7%, with only a minute percentage requiring operative intervention.[56,85,86] Neovesical-urethral anastomotic leaks most often spontaneously close with continued drainage and decompression of the neobladder.

When evaluating anastomotic leak, the surgeon must rule out outlet obstruction as a cause. Urinary retention resulting from mucus obstruction occurs between 1.2% and 4.6% of the time and can contribute to anastomotic leakage as well as the rare but potentially devastating complication of neobladder perforation.[16,87] Regardless of whether a suprapubic tube (which incidentally, we no longer routinely use) is placed in the neobladder in conjunction with the urethral catheter, regular irrigation of the neobladder in the initial postoperative period decreases mucus retention and facilitates emptying to reduce neobladder-urethral anastomotic leakage and allow optimal healing.

It is also critical to ensure that the Foley catheter is in the proper position and that it has not migrated out of the neobladder into the urethra. We generally use a 20- or 22Fr Foley catheter with a 10-mL balloon and inflate the balloon to 15 mL to allow a spherical configuration. A larger catheter is necessary to allow for irrigation of mucus or blood clots in the early postoperative period. Occasionally it may be useful to manipulate the placement of the drain lying on the anastomotic suture line to ensure that the drain itself is not perpetuating the leak.[87] A cystogram may be performed before drain or catheter removal to ensure complete closure at the urethral anastomosis. For prolonged urine leakage or in patients who develop metabolic derangements from urinary extravasation, bilateral percutaneous nephrostomy tubes can be placed for temporary diversion along with a Foley catheter and pelvic drain. Prevention of urethral anastomotic leaks may be aided by meticulous mucosa-to-mucosa approximation of a tension-free suture line and avoidance of overdistention of the neobladder resulting from catheter malfunction or mucus plugging.

A later complication of the neovesical-urethral anastomosis is stricture, which often manifests as difficulty with neobladder emptying. The reported incidence of this complication is approximately 2.4–9%.[16,56,58,86,88,89] Failure to empty after orthotopic urinary diversion necessitates cystoscopic and radiographic examination to differentiate between dysfunctional voiding and neovesicourethral obstruction. Dysfunctional voiding commonly results from an unsuitable size or shape of the neobladder; from the position, length, or angulation of the neobladder neck; or from a denervated proximal urethra. In contrast, neovesicourethral obstruction is caused by stricture, distal urethral obstruction, local tumor recurrence, cystolithiasis, or obstructive mucosal valves.[88]

Cystoscopy is the primary diagnostic tool allowing direct visualization of the bladder neck and quantitative assessment of the anastomotic stricture. Other diagnostic modalities such as transrectal ultrasound of the vesicourethral anastomosis, ultrasound of post-void residual, cystography, and CT or magnetic resonance imaging of the pelvis can further assist in differentiating dysfunctional voiding from anastomotic stricture.

Treatment options for anastomotic strictures vary from conservative management with continuous or intermittent catheterization, dilation at the level of the bladder neck, transurethral resection of transurethral incision of the bladder neck with cold knife, electrocautery, or holmium laser. Although many of these strictures can be managed with transurethral incision or resection, it is paramount to sample tissue and exclude recurrent cancer as a cause. In addition, vigilant follow-up is required to identify early recurrent strictures and to ensure proper emptying and prevent neobladder rupture. Patients whose neobladder becomes overdistended as a result of outlet obstruction should be instructed to perform intermittent catheterization to ensure proper emptying because the tonicity of the neobladder may not return to baseline. This approach may also serve to check that the stricture has not recurred and that the anastomosis is widely patent.

URETEROINTESTINAL ANASTOMOTIC COMPLICATIONS

One of the most difficult complications of urinary diversion is breakdown or stricture of the ureterointestinal

anastomosis. Once again, basic surgical tenets are paramount in reducing or preventing anastomotic complications. During mobilization of the ureters, great care must be taken not to devascularize the distal ureter, and adequate length must be achieved to avoid tension on the anastomosis. Care must be taken to avoid kinking of the left ureter as it is passes beneath the mesentery of the sigmoid colon. Additionally, every effort should be made to create a watertight anastomosis with absorbable suture material, to spatulate the ureter to ensure adequate luminal diameter, and to ensure careful placement of apical sutures.

The incidence of ureteroenteric anastomotic leak decreased significantly with the routine use of soft Silastic stents placed across the ureteroenteric anastomosis at the time of diversion.[12,90] This technique is now used almost universally and has a reported rate of urinary leakage of approximately 3%.[56] Studies have investigated placement of self-retaining ureteral stents following neobladder diversion with a similar incidence of complications.[91] Of course, stents alone do not eliminate complications of ureteroenteric anastomosis and can lead to additional complications when they are improperly positioned or are inadvertently sutured to the ureter. Furthermore, obstruction or infectious complications including urosepsis may result from occluded ureteral stents.

Ureteral stents are routinely removed before the removal of the pelvic drain. Anastomotic urinary leakage is suspected when drain output is increased or when urinary drainage from the wound is noted, particularly in the setting of decreased urine output. Suspicion of urinary leakage should trigger prompt assessment. Evaluation of the suspected fluid for creatinine content is usually the first step. If the creatinine concentration in the fluid is higher than that of the serum, further testing should include imaging such as a CT scan or cystogram to identify the site of urinary extravasation. Most often, initial management is conservative, involving adequate drainage of the neobladder, with consideration of placement of a percutaneous nephrostomy tube along with continued closed-suction drainage and close monitoring. If leakage persists, usually antegrade stent placement through the nephrostomy will be attempted. Rarely is surgical intervention necessary in the early postoperative period for this complication.

Urinary leakage at the ureteroenteric anastomotic site can lead to periureteral fibrosis and predispose to stricture formation. Other causes of stricture include tension at the anastomosis, ischemia of the ureter, infection, and recurrence of cancer. The incidence of ureteroenteric stricture is between 2% and 9%. [16,30,56,75,86,92] Ureteral strictures can also occur away from the anastomosis where the left ureter crosses beneath the inferior mesenteric artery.

An exhaustive review of specific ureteroenteric anastomotic techniques is beyond the scope of this chapter, but considerable debate remains about whether a nonrefluxing or refluxing anastomosis is most desirable for orthotopic urinary diversion.[12,87,93] Arguments for provision of an antireflux mechanism include the potential harmful effects on renal function secondary to recurrent pyelonephritis from reflux of colonized urine.[8] Primary opinions supporting a refluxing anastomosis describe a higher incidence of obstruction with the antirefluxing mechanism; these proponents also argue that the neobladder is a low-pressure reservoir and that urine is assumed to be sterile. Studies addressing renal function indicate no detrimental effect on renal function in patients who have neobladders without an antireflux mechanism at an average follow-up of 50 months.[94] However, upper urinary tract deterioration may need to be measured over decades, not months.[12]

Other series additionally indicate a higher level of upper urinary tract deterioration with antirefluxing techniques as a result of stricture formation and obstruction.[95,96] A large cohort with >350 patients who received a Hautmann neobladder with a LeDuc antirefluxing anastomosis had a ureteroenteric stricture rate of 9.3% at average follow-up of 54 months.[97] Abol-Enein and Ghoneim[98] reviewed >300 patients who received a Hautmann neobladder with an antirefluxing serous-lined extramural tunnel technique and reported a 3.8% rate of stricture with unspecified follow-up.

In a series of 166 Kock ileal neobladders in which the ureteroenteric anastomosis was performed with a refluxing end-to-end Wallace technique, the stricture rate was only 0.6% with follow-up of 2.7 years.[99] In a cohort of 32 patients with refluxing ureteroileal anastomosis into a Studer limb, <1% of renal units developed a stricture with 2-year follow-up.[100] Another study examining 130 patients who received either a Studer or a Hautmann neobladder with a refluxing end-to-side Bricker anastomosis found only three ureteroenteric strictures at a mean follow-up of 20 months.[101] Thus the rate of ureteroenteric stricture has varied greatly among the large neobladder series that have incorporated both refluxing and nonrefluxing anastomosis, although the general trend reveals lower stricture rates with nonrefluxing anastomoses.

To date, studies evaluating the different anastomotic techniques that are well designed, prospective, and randomized, with appropriate numbers and long-term follow-up, have not been performed. We believe that a simple end-to-side, freely refluxing anastomosis to an afferent limb of a low-pressure neobladder is sufficient and has an acceptably low rate of anastomotic stricture.

Regardless of the technique used for ureterointestinal anastomosis, prompt diagnosis and treatment of anastomotic strictures are paramount to preserve renal function. Although many patients are asymptomatic and the diagnosis is made by the presence of hydronephrosis on routine surveillance imaging, patients with ureteroneobladder strictures may present with flank pain, pyelonephritis, or renal insufficiency.

Ureteroenteric stricture can be diagnosed with IVP, CT scan, or antegrade nephrostogram if obstruction is of high grade and percutaneous intervention with nephrostomy placement is indicated (Fig. 47.2). It is imperative that tumor recurrence be excluded in these patients before a specific treatment is initiated. This goal is usually accomplished through a combination of radiographic, endoscopic, and cytologic evaluations. In addition, the function of the involved renal unit should be determined, and in patients with poorly functioning units (<15%), strong consideration should be given to the performance of simple nephrectomy.

Several techniques have been used to treat ureteroenteric strictures including balloon dilation, endoscopic incision with both antegrade and retrograde approaches, and open revision.[87,102] In addition to the potential presence of malignant disease, factors considered in determining the optimal operative strategy must account for the length of the stricture



Figure 47.2 Ureterointestinal stricture. Note the dilation of the proximal collecting system above the stricture at the distal ureter in this nephrostogram. Some contrast material still passes through the stricture into the neobladder.

and the history of prior irradiation to the area. Endourologic procedures using balloon dilation have been reported, although success rates are generally no better than 29% with long-term follow-up.[102] Endoscopic incision of strictures has been employed with short-term success rates of approximately 70%.[103] Longer follow-up was not as favorable in this series, which had only a 32% patency rate after endourologic treatment of ureteroenteric strictures at 3 years.

The best results have been seen with short (<2 cm) distal strictures treated when the patient's renal function remains good. Leaving a stent of ≥12Fr for ≥4 weeks also may increase success rates. Data also suggest improved outcome with local injection of steroids (triamcinolone) into the stricture bed following surgical incision. Success was universally poor for endoscopic treatment in renal units with <25% function.

Open surgical correction with excision of the stenotic segment and revision of the anastomosis yields the highest rate of success but with the tradeoff of a technically challenging and potentially morbid procedure. Anastomotic revision is assisted by placement of an antegrade stent abutting or even through the anastomotic stricture to assist in the intraoperative identification of the ureter. This technique is particularly useful in the setting of dense adhesions and fibrosis in which initial identification of the ureter may be difficult. Similarly, a catheter is placed in the neobladder to allow for intraoperative identification. It may also be necessary to revise the contralateral ureteral anastomosis in the event that it is in close proximity to the area of repair. Furthermore, care must be taken during dissection to avoid injury to the contralateral nonobstructed ureter as scarring and fibrosis may distort ureteral anatomy.

After recognition and excision of the ureteral stricture, the ureter is spatulated and reanastomosed to the orthotopic diversion. In general, the neobladder enjoys more redundancy than does the ureter, which is often encased in a fibrotic reaction. It is important to evaluate the excised segment of strictured ureter by frozen section pathologic analysis to rule out malignant disease. In the case of large ureteral defects, ileal interposition, transureteroureterostomy, or even nephrectomy may be necessary. These patients should undergo full mechanical and antibiotic bowel preparation to minimize complications and to maximize intraoperative surgical options.

The success rate of open revision of ureterointestinal strictures approaches 90%.[87,104] Not surprisingly, left ureteroenteric strictures are often more difficult because of the longer course and pathway under the sigmoid mesentery. Right ureteroenteric strictures may in certain circumstances be approached from a completely extraperitoneal approach.

UROLITHIASIS

Urolithiasis in neobladders can be caused by a variety of factors including metabolic derangements, retained mucus, urinary stasis, and chronic infection.[105] Current opinion is that neobladders are less often colonized compared with continent cutaneous diversions unless long-term catheterization is needed.[106] Reservoirs created with exposed metallic staples have a significantly higher incidence of urolithiasis. Series with the orthotopic Kock neobladder in which exposed permanent staples were used to create the intussuscepted nipple valve reported urolithiasis in the range of 30% at 3-year follow-up.[99] The use of absorbable staples for the afferent nipple valve construction in the Kock neobladder reduced the rate of stones to 4%.[107]

More recent series that did not use staples in neobladder construction reported much lower rates of urolithiasis in the range of 0.5–3%.[98,108] For patients with limited stone burden within the neobladder, transurethral techniques may be used, although some investigators favor a percutaneous or open approach to avoid compromising the continence mechanism of the neobladder.[105]

Upper tract calculi are also common complications of urinary diversion. Urinary stasis resulting from chronic dilation is likely a major culprit in stone formation. Most upper urinary tract calculi appear on the left side, a finding suggesting causality with mobilization and transposition of the left ureter.[109] Contemporary treatments include all modalities of management from shock wave lithotripsy to percutaneous nephrolithotomy.[109–112] Planning an operative strategy naturally depends on the stone burden, location, likely composition, and anatomic considerations, as well as the surgeon's comfort with procedures. Retrograde endoscopic management is particularly difficult in orthotopic neobladder diversions even with nonrefluxing anastomoses, and a combination of alternative modalities are often used. Accordingly, almost all ureteral and renal pelvic stones requiring endoscopic intervention are approached by an antegrade percutaneous technique.

URINARY TRACT COLONIZATION AND PYELONEPHRITIS

Bacterial colonization of the neobladder diversion occurs in 40–80% of patients.[113–115] Colonization is strongly associated with both residual urine[116] and the need to perform

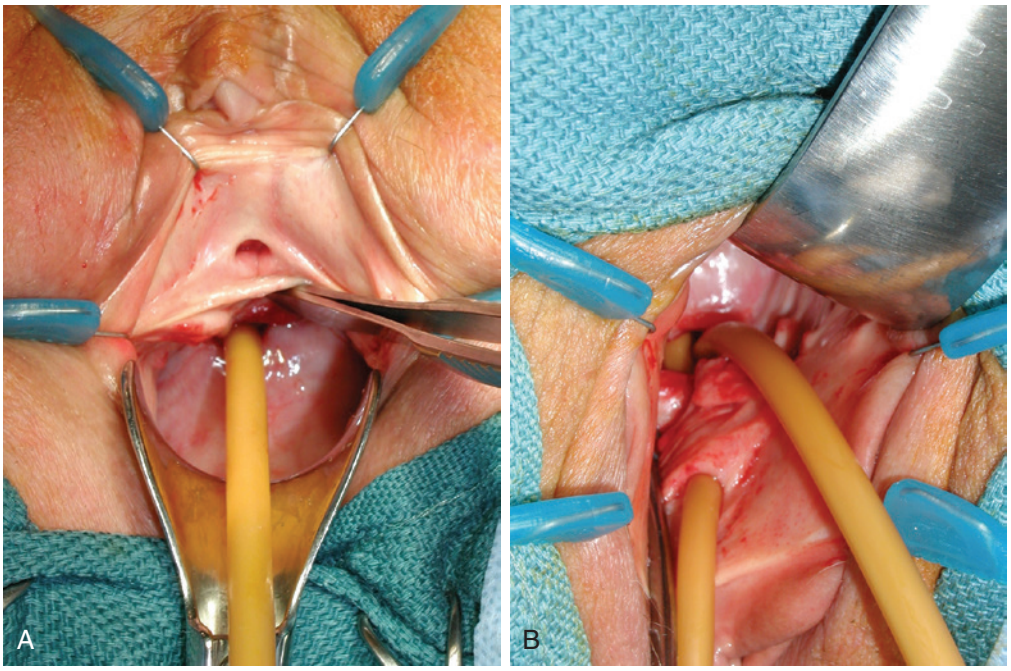


Figure 47.3 Neobladder-vaginal fistula visualized in (**A**) lithotomy and (**B**) prone positions. A catheter is placed into the neobladder through the fistula tract. The urethra is additionally shown catheterized in the prone position.

self-catheterization.[117] Treatment of the neobladder bacteriuria remains a controversial topic in that approximately half of these patients remain asymptomatic from the infection.

In a prospective evaluation of 66 patients with neobladders who were evaluated with urinalysis and culture 2 months to 4 years postoperatively,[114] 55 patients voided normally and 11 performed intermittent catheterization at least once daily as a result of high post-void residual urine. Of the patients who voided normally, 78% had at least one positive urinalysis, and of these bacteria was identified on culture in 50%. Overall, 26 (39%) and 8 (12%) patients had urinary tract infection and urosepsis, respectively. The estimated 5-year probabilities of urinary tract infection and urosepsis in patients who voided independently were 58% and 18%, respectively. Urine culture with >100,000 colony-forming units and female gender were the only factors predictive of urinary tract infection on multivariate analysis. Recurrent urinary tract infection was the only predictor for urosepsis. These investigators recommended prophylactic antibiotics only for patients with recurring urinary tract infections but did not advocate treating patients with a positive urinary culture in the absence of symptoms. However, it is recommended that treatment be pursued in patients with urea-splitting organisms because of the high risk of stone formation.[106]

Approximately 6% of patients with neobladders progress to overt pyelonephritis at some point following urinary diversion.[16] In the absence of obstruction, upper urinary tract infections can be managed with administration of culture-specific antibiotics.

FISTULAS

When indications for orthotopic diversion were initially extended to female patients, surgeons were appropriately concerned about the rate of neobladder-to-vagina fistula.[118,119] Fortunately, neobladder-vaginal fistula formation was reported at <5% in multiple series[98,120,121] (Fig. 47.3). Surgical refinements that decreased fistula formation include the avoidance of overlapping suture lines and the interposition of omentum when the anterior vaginal wall has been incised or partially excised. When oncologic control is not compromised, the ideal technique includes avoidance of entry into the vagina and preservation of the anterior vaginal wall.[121,122] Most fistulas that develop in the setting of a female neobladder require surgical intervention, and they often are not amenable to repair without complete mobilization and subsequent interposition of omentum or myocutaneous flap.

A dreaded complication of neobladder diversion is the development of enterocutaneous or neobladder-enteric fistulas. Mortality is pronounced with these abnormal communications, so diagnosis and treatment must be prompt. As addressed earlier, poor nutritional status, anastomotic leak, devascularization of tissue during the surgical procedure, steroid use, multiple medical comorbidities, and unprepared bowel all contribute to fistula formation.[64] Enterocutaneous fistulas often manifest between 4 and 7 days postoperatively but of course may become apparent at any time during the follow-up. Patients generally present with fever, leukocytosis, metabolic derangements, and signs of cellulitis that progress to frank spillage of enteric contents onto skin.

Broad-spectrum antibiotics should be briskly administered to ward off sepsis, and CT scan of the abdomen should be obtained to rule out intraabdominal abscess. Following supportive treatment and stabilization, a fistulogram may assist in localizing the tract and in determining whether further conservative management is merited. In cases of obvious peritonitis, exploration with or without bowel

diversion is necessary. In the absence of infection, in patients with sufficient bowel rest and supplementation of nutritional status with either a low-residue diet or total parenteral nutrition, 60–80% of enterocutaneous fistulas spontaneously close. For the remainder of patients, operative management is preferable within 6 weeks of the initial diagnosis.

Fistulas between the small or large bowel and neobladder may be more insidious in onset and may manifest with pneumaturia, fecaluria, diarrhea, and general abdominal symptoms. The diagnosis is often confirmed by a traditional or CT cystogram (Fig. 47.4). In the absence of gas-producing organisms, the finding of air in the anterior portion of a noninstrumented patient on CT scan should arouse strong suspicion of this fistula. Again, conservative measures, which in this case include neobladder catheter drainage and bowel rest with TPN, may allow healing of small fistulas,[123,124] but definitive operative management often becomes necessary.[125] At the time of surgical correction, the surgeon should obtain a biopsy sample of the fistula site to exclude recurrent malignant disease as the underlying cause. Rare cases of vascular fistulas with orthotopic diversion have been reported and successfully treated with endovascular repair.[126]

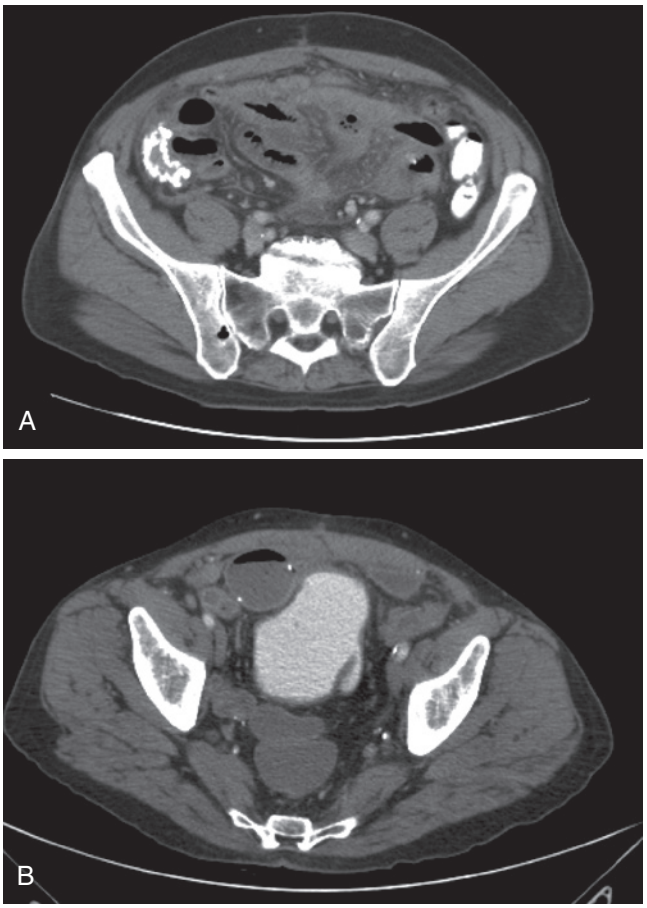


Figure 47.4 Neobladder-enteric fistula on CT cystogram. A, Note the presence of gas in the fluid collection anterior to the neobladder that is suggestive of fistula. B, Cystogram reveals the fistula tract on the left lateral aspect of the neobladder.

VOIDING DYSFUNCTION

The perceived improved quality of life of the orthotopic neobladder as compared with incontinent diversion may be significantly reduced or eliminated in patients with severe voiding dysfunction.[127] Daytime incontinence may range from mild stress incontinence to total incontinence in a small percentage of patients, but complete daytime continence is achieved in close to 90% of patients with neobladders.[16] Approximately 20–50% of patients experience some degree of nighttime incontinence. Alternatively, approximately 8% of patients may develop hypercontinence or high post-void residuals requiring self-catheterization.[87,128] Hypercontinence is more prevalent among women due to overly acute neocystourethral angle from downward migration of the neobladder and is as high as 15% among women.[129] Hypercontinence is also particularly common following an episode of urinary retention in which the bladder may become silently overdistended and may fail to recover its natural tonicity.

A comparison of the severity and incidence of voiding dysfunction among various surgical series is confounded by the variability in definitions, end points, surgical technique, and length of follow-up. Additionally, symptoms have rarely been assessed using validated instruments. With these limitations noted, a review of >2000 patients with orthotopic neobladders did provide a clear characterization of associated voiding dysfunction. This meta-analysis showed that 4–25% of patients with orthotopic neobladders performed intermittent self-catheterization for incomplete emptying. Daytime incontinence was present in approximately 13% of patients.[127]

As with the fashioning of other types of urinary diversion, general surgical principles must be maintained to maximize chances of optimal functional outcomes and to reduce complications. The neobladder must be constructed such that it can accommodate a sufficient volume under low pressure with limited absorption of urine.[12] Intrinsic to the spheroid shape of the reservoir are mathematical principles that dictate the optimal length of bowel to achieve the desired capacity, as pressure is inversely related to the radius according to Laplace's law.[83] Ideally, a segment of bowel 50–55 cm in length is selected. If the segment is too small, the capacity will be low and will risk unnecessary and avoidable incontinence and urinary frequency.[130] Similarly, if too generous a segment of bowel is selected, poor emptying and urinary retention will ensue. Poor emptying can precipitate not only the need for lifelong self-catheterization but also distention and the rare but devastating complication of neobladder perforation.[131,132]

A report of a large series of neobladder emptying failures in men demonstrated an 8% incidence of mechanical dysfunction and a 3.5% incidence of dysfunctional voiding.[88] The investigators indicated that vigilant reservoir emptying to prevent excessive neobladder distention had a more profound impact on voiding function than did the length of bowel used and the corresponding size of the initial pouch.

During cystectomy, particular attention should be directed toward preserving the rhabdosphincter to protect the continence mechanism.[12,133] In men, the apical prostate dissection should be performed in a manner similar to that

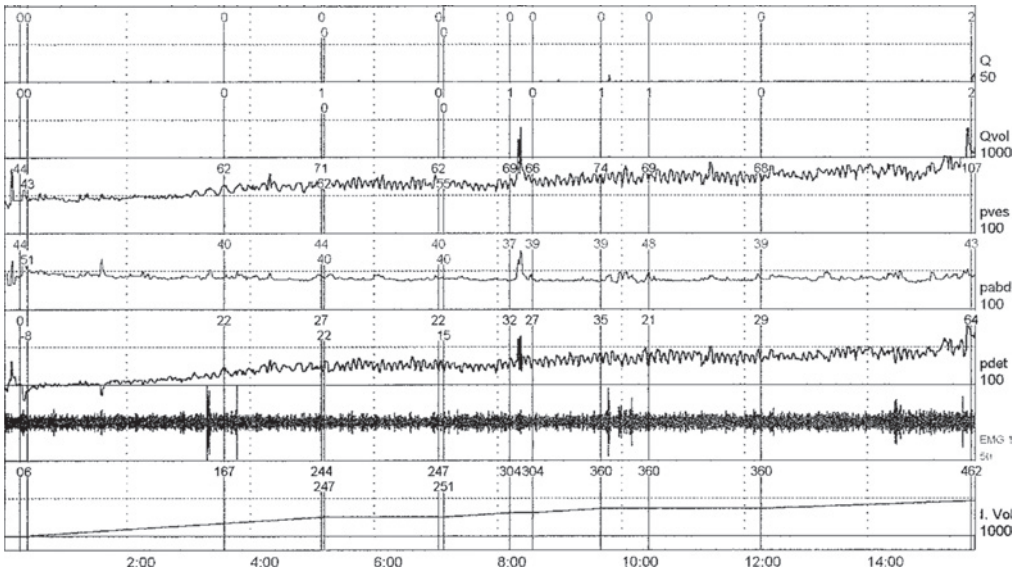


Figure 47.5 Urodynamic tracing of neobladder cystometry in a patient with voiding dysfunction. Note the hyperactivity of the neobladder in the detrusor pressure (pdet) tracing, which reveals neobladder overactivity. EMG, electromyogram; pabd, abdominal pressure; pves, total bladder pressure; Qvol, voided volume.

of radical prostatectomy. In women, the urethra and uninvolved bladder neck are preserved. In addition, a plane of dissection can be carried posterior to the bladder and just above the anterior vaginal wall to preserve urethral innervation. It is also important to handle and preserve vaginal tissues, the levator muscle, and pelvic floor fascia gently. Finally, positioning the neobladder neck in the most dependent portion of the pelvis ensures proper funneling of the bladder outlet on voiding.

Urodynamic study is now frequently used to determine causes of dysfunctional voiding in the patient with a neobladder. Indeed, despite bowel detubularization,[134] uninhibited contractions resulting in incontinence may occur in almost half of reservoirs (Fig. 47.5).[135,136] These patients often benefit from pharmacologic intervention with anticholinergic agents to decrease neobladder overactivity. Women with de novo stress urinary incontinence following neobladder placement may be candidates for placement of a pubovaginal sling in a modified fashion so the areas of previous surgical intervention are avoided.[137]

In addition to aiding continence, careful neurovascular preservation appears to assist with preservation of sexual function in both male and female patients.[138–140] However, some analyses suggest that sexual function–preserving cystectomy may compromise oncologic control.[141]

URETHRAL AND PELVIC TUMOR RECURRENCE

The historical incidence of urethral recurrence following cystectomy is 10%,[142] but urethral recurrence with ileal neobladder in both male and female patients has been reported in the range of 0.5–5%.[58,143–146] This discrepancy is likely the result of both patient selection bias and careful intraoperative evaluation of the urethral margin with frozen section analysis before construction of an orthotopic reservoir.[147,148] Although surveillance cystoscopy or urethral washing for cytologic examination is generally advocated for screening following orthotopic diversion, large series demonstrated that the majority of patients with urethral recurrence actually developed symptoms that led to the diagnosis (discharge, pain, palpable mass) and the presence of positive cytologic findings did not affect stage or survival.[149,150] Additionally, the sensitivity of urethral wash cytology is extremely low.[151]

Most recurrences are detected within 5 years of cystectomy,[152] but lifelong screening is required because urethral tumors have been found ≤15 years after initial surgical treatment.[153] Whether these tumors actually represent recurrences of the original tumor or are a consequence of the field changes known to occur with urothelial cell cancers is unclear. However, once urethral recurrence is diagnosed, treatment depends on the type of recurrence. For invasive urothelial carcinoma, urethrectomy and conversion of the orthotopic diversion to an incontinent diversion are the therapeutic procedures of choice. Patients with carcinoma in situ have been successfully treated with bacille Calmette-Guérin (BCG) with an 83% response rate.[154] Superficial recurrences have also been managed with endoscopic resection.[143,155]

Pelvic recurrences occur in approximately 7% of patients who have undergone cystectomy,[156] but large-scale analyses indicated that local recurrence with functional impingement on the neobladder that requires resection is rare.[16] In one series, Freeman and colleagues[157] found an overall local recurrence rate of 11% in a study of predominantly male patients with orthotopic neobladders. A similar rate of pelvic recurrence (14%) was reported in another series examining patients with unfavorable histologic features.[158] In these series, one-half to two-thirds of patients with pelvic disease recurrence retained adequate neobladder function despite death from the disease. In another study, the type of urinary diversion did not change the risk of complications, the response to salvage treatment, or overall survival in patients with pelvic recurrences.[159] In rare circumstances, an ileal conduit or palliative diversion is necessary because of local tumor invasion of the neobladder.

Among women, the rate of pelvic disease recurrence after anterior exenteration was <5% in two separate studies, but in both series the recurrences were in patients without transitional cell carcinoma.[119,160] In a study of patients with squamous cell carcinoma, the pelvic recurrence rate was 12%.[161] Thus, female patients with squamous cell carcinoma and those with nonurothelial histologic features may be at higher risk for local recurrence and may not be appropriate candidates for vaginal sparing. When the anterior vaginal wall was preserved during cystectomy and neobladder formation among women with transitional cell carcinoma, the local recurrence rate was 5%.[121]

NEOBLADDER RUPTURE

Spontaneous rupture of an orthotopic neobladder has been reported to occur in 1.5–4.3% of patients.[131,162] This complication is most commonly the result of acute or chronic overdistention of the neobladder. However, other causes include instrumentation, catheter trauma, mucus retention, and altered sensorium from drug or alcohol effects. Patients prone to overdistention or excess mucus production must be instructed to be vigilant in continuous intermittent catheterization as frequent as every 4 hours to avoid this uncommon but occasionally life-threatening complication. Patients with orthotopic diversions should be instructed to wear medical alert bracelets to inform medical personnel in the event of an emergency.

The presentation of spontaneous orthotopic neobladder rupture is generally that of acute abdominal pain accompanied by abdominal distention and decreased urine output. In the setting of infection, the patient may present with peritonitis or sepsis. An initial attempt should be made to place a Foley catheter in the neobladder. A cystogram can then be performed to evaluate for extravasation. In addition to a standard CT scan of the abdomen and pelvis, a CT cystogram may be revealing. A high index of suspicion should be maintained if a large amount of free fluid likely representing urine is demonstrated on the CT scan even in the absence of extravasation on cystogram.

The presentation and overall clinical features in part dictate the magnitude of treatment for neobladder rupture. Patients without signs of overt peritonitis or sepsis may be managed initially with conservative measures including catheter drainage, broad-spectrum antibiotics, and careful monitoring of vital signs and urine output.[163] However, patients with altered mental status, intractable pain, hemodynamic instability, or frank peritonitis should undergo emergency surgical exploration. Exploratory laparotomy with drainage of peritoneal urinary ascites and repair of neobladder rupture should be performed. A large-caliber intraperitoneal drain and large-caliber Foley catheter should be placed for postoperative management. Generally, the Foley catheter is removed after 3 weeks, any underlying cause of the complication is corrected, and the patient is monitored closely to ensure that neobladder compromise does not recur.

References

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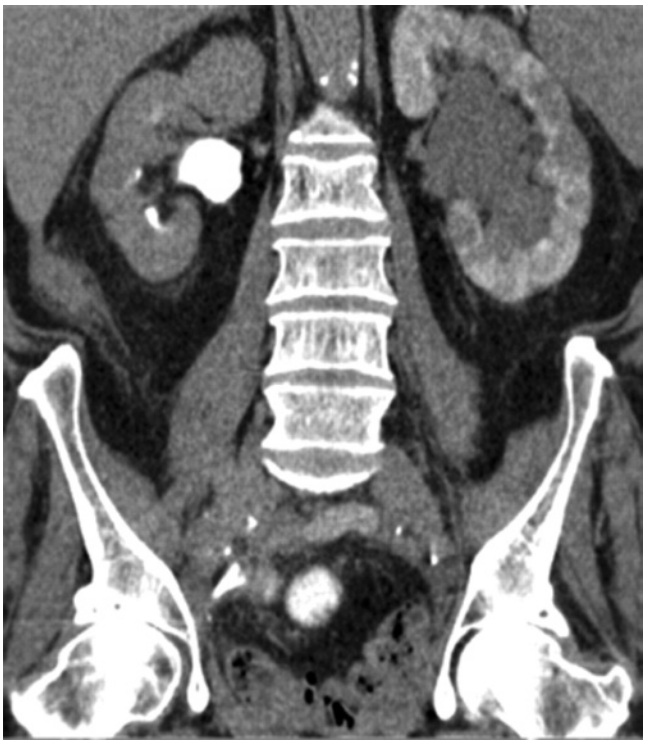
Chapter 47 Questions

1. A 65-year-old man with muscle invasive bladder cancer undergoes radical cystoprostatectomy with orthotopic neobladder. Four months after surgery he notes passage of stool contents per urethra and pneumaturia. He undergoes CT cystogram, which shows a small fistulous connection between his neobladder and sigmoid colon. The patient has stable vital signs and otherwise has no other complaints. He empties his neobladder every 3–4 hours and has a PVR in clinic of 15 mL. He has daily bowel movements and denies constipation. Flexible cystoscopy is performed in clinic, which reveals an erythematous 0.5-cm fistulous connection that has mild evidence of bleeding. Biopsy of this site is negative for recurrence of cancer. What is the next step in the management of this patient?
   a. Cystoscopy and fulguration of the fistula
   b. Surgical exploration with excision of the fistula tract
   c. Bilateral percutaneous nephrostomy tube placement
   d. Bowel rest, total parenteral nutrition (TPN), and urethral catheter placement
   e. Colonoscopy and placement of colonic stent

2. A 70-year-old man undergoes radical cystoprostatectomy for muscle invasive bladder cancer with a Studer neobladder urinary diversion. He presents to the ER 6 months after his procedure where he is noted to have fever of 102.1°F, heart rate of 95, blood pressure of 110/54 mm Hg, white blood cell count of 15.1 × 10^9/L, and an elevation in his serum creatinine level to 1.6 mg/dL. He states he has had worsening left-sided flank pain and fatigue. He has been emptying his neobladder every 3–4 hours without any problems and has a post-void residual urine of 20 mL. CT scan is obtained with the delayed phase as shown in Case Fig. 47.1. He is started on broad-spectrum IV antibiotics. The best next step in the management of this patient is:
   a. Placement of urethral catheter
   b. Cystoscopy and retrograde ureteral stent placement
   c. Left percutaneous nephrostomy tube placement
   d. Surgical exploration and ureteral reimplantation
   e. Urethral catheter placement with a cystogram

3. Which of the following is an absolute contraindication to orthotopic neobladder diversion?
   a. Positive pelvic lymph nodes
   b. Renal insufficiency with serum creatinine of 1.4 mg/dL
   c. Hepatic insufficiency
   d. History of left hemicolectomy
   e. History of transurethral resection of the prostate (TURP)

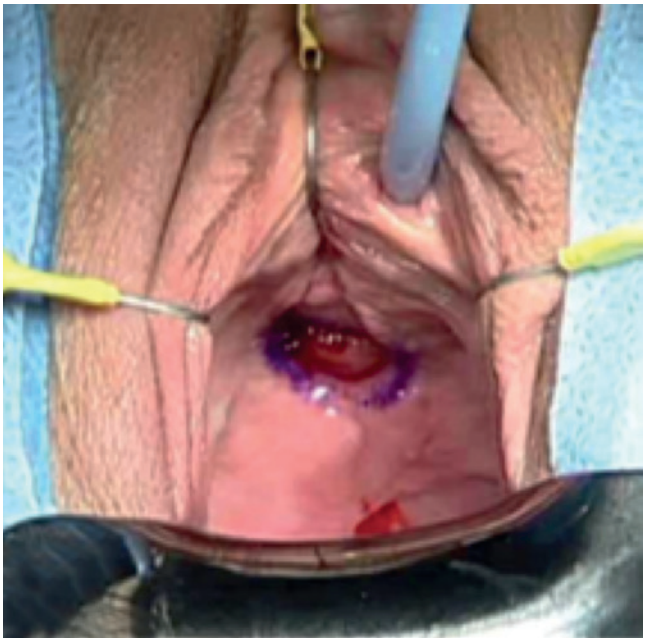
4. A 70-year-old man with a neobladder urinary diversion is admitted to the hospital after falling down a flight of stairs. He is taken to the ER where his vital signs are within normal limits, with normal CBC and BMP. He is diagnosed with a left clavicular fracture per x-ray imaging. His physical exam is otherwise unremarkable with the exception of a distended abdomen. He undergoes CT scan which shows a large amount of free fluid in his abdomen. The next step in the management in this patient is:
   a. Emergent exploratory laparotomy
   b. Cystoscopy with incision of bladder neck contracture
   c. Percutaneous drain placement
   d. Placement of urethral Foley catheter and cystogram
   e. Percutaneous drain placement with bilateral nephrostomy tube placement



Case Figure 47.1

5. All of the following are causes of stone formation in neobladders except:
   a. Retained mucus
   b. Urinary stasis
   c. Chronic infection
   d. Use of colon instead of ileum for neobladder
   e. Use of metal staples for creation of neobladder

6. A 56-year-old woman undergoes vaginal sparing cystectomy with ileal neobladder creation. She tolerated the procedure well and is discharged home on postoperative day 7. Her pathology revealed a pT1 tumor at the dome of the bladder with 0 of 20 nodes positive for disease. She returns for follow-up 8 weeks later complaining of progressively worsening urinary leakage and is wearing 10 pads per day. She states that her leakage is worse during the nighttime and is not associated with Valsalva. Her post-void residual urine in clinic is 5 mL. Her physical examination is shown in the picture in Case Fig. 47.2 and confirms a neobladder to vagina fistula. The most common cause of early neobladder-vaginal fistula is:
   a. Extravasation of urine
   b. Displacement of urethral anastomosis from hematoma



Case Figure 47.2

c. Damage to the anterior vaginal wall during cystectomy
d. Disease recurrence at urethral margin
e. Acute neovesical-urethral angle

7. A 70-year-old man underwent neobladder diversion 5 years prior. He presents to the ER with delirium, fever up to 101.9°F, tachycardia to 110, and leukocytosis of 18×10^9/L. His wife tells you that he has been dribbling urine over the last week. His post-void residual is 900 mL. He is started on IV antibiotics. The next step in management is:
   a. Cystoscopy with placement of a guidewire, dilation, and catheter placement
   b. Bilateral nephrostomy tube placement
   c. Open suprapubic tube placement
   d. Open revision of a neovesical-urethral anastomosis
   e. Transurethral resection of a bladder neck contracture

8. A 73-year-old man underwent neobladder urinary diversion. One year later he experiences elevated post-void residuals up to 700 mL with weakening of his stream and is diagnosed with a bladder neck contracture. He undergoes cystoscopy and incision of a pinpoint bladder neck contracture using a holmium laser. The most common cause of his bladder neck contracture is:
   a. Extravasation of urine after neobladder surgery
   b. Prolonged postoperative urethral catheter placement
   c. Recurrent urinary tract infections
   d. Bladder stone formation
   e. Traumatic Foley placement

9. A 68-year-old man with neobladder urinary diversion presents to the ER with a 3-day history of left flank pain and is diagnosed with a 1.0-cm left ureteropelvic junction (UPJ) stone with moderate hydronephrosis and a 1.5-cm lower pole stone. His vital signs are within normal limits, and his pain is controlled with oral narcotics. The management strategy with the highest success rate is:
   a. Cystoscopy and retrograde ureteroscopy and laser lithotripsy
   b. Alkalization of urine
   c. Acidification of urine
   d. Extracorporeal shock wave lithotripsy (ESWL)
   e. Percutaneous nephrolithotomy (PCNL)

10. A 67-year-old woman with extensive cT2 bladder cancer at her bladder neck presents to your clinic for evaluation for ileal neobladder. She has a history of a left hemicolectomy for diverticular disease and her Cr is elevated to 1.6 mg/dL. She has baseline stress urinary incontinence of one pad per day. Which of the following would preclude her from neobladder diversion?
    a. Elevated creatinine
    b. History of left hemicoletomy
    c. Disease the bladder neck
    d. Stress urinary incontinence
    e. Age >65

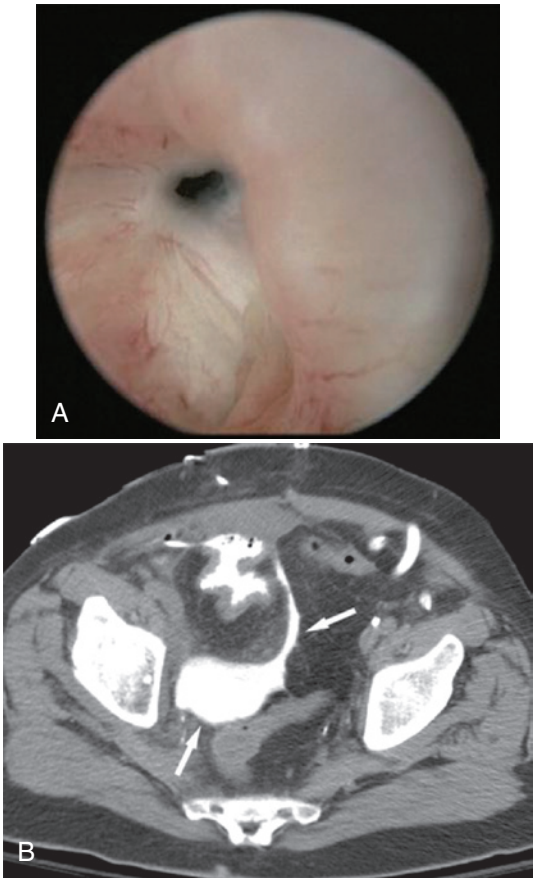
Case Studies

CASE 1

A 68-year-old man who underwent neobladder urinary diversion 9 months ago presents to the ER with 1-day history of severe abdominal pain. He states that he has had a progressively worsening stream over the last few weeks and has been straining to empty his neobladder. His vital signs in the ER are significant for tachycardia with heart rate of 110 and fever of 101.1°F. His blood pressure is 110/65 mm Hg. On exam his abdomen is diffusely tender to palpation and is mildly distended. The patient's bladder scan shows 900 mL in his bladder. His white blood cell count is 15.1×10^9/L, with an elevation in his serum creatinine level to 1.6 mg/dL from baseline of 0.9 mg/dL. The nursing staff attempt to place a Foley catheter but are unble to do so. Urology is consulted for Foley catheter placement. Bedside cystoscopy is performed and the scope is unable to be passed into the bladder (Case Fig. 47.3A).

1. The next best step in management is:
   a. Bilateral nephrostomy tube placement
   b. Cystoscopy in OR with transurethral incision of the bladder neck
   c. Open suprapubic tube placement
   d. Interventional radiology consult to place a percutaneous suprapubic tube
   e. Cystoscopy with placement of a guidewire, dilation, and catheter placement

After the catheter is placed the patient is admitted for monitoring and administration of IV antibiotics. He continues to have continued abdominal pain overnight. He is afebrile, has normalization of his heart rate, and continues to have a stable blood pressure. CT cystogram is performed (Case Fig. 47.3B).



Case Figure 47.3

2. The best next step in management is:
   a. Exploratory laparotomy
   b. Bilateral nephrostomy tube placement
   c. Broadening of IV antibiotics
   d. Interventional radiology consult to place a percutaneous drainage tube into the fluid collection
   e. Bowel rest with nasogastric (NG) tube placement and total parenteral nutrition (TPN)

The patient clinically improved after drain placement and ultimately had the drain removed 2 weeks later after the drainage was less than 100 mL per day and the creatinine level from the drain was serum. He had a cystogram 3 weeks later that showed no evidence of a leak, and his Foley catheter was removed. One month later the patient states that he is having a worsening urinary stream. Cystoscopy in clinic reveals a recurrent bladder neck contracture. His PVR in clinic is 200 mL.

3. The next best step in management is:
   a. Open revision of bladder neck
   b. Cystoscopy in OR with transurethral incision of the bladder neck and catheter placement
   c. Open suprapubic tube placement
   d. Interventional radiology consult to place a percutaneous suprapubic tube
   e. Cystoscopy with placement of a guidewire, dilation, and catheter placement



Case Figure 47.4

CASE 2

A 54-year-old woman underwent orthotopic urinary diversion 4 year ago. Since her procedure she has had several febrile urinary tract infections, which have been treated with oral antibiotics. Her PVR in clinic is 300 mL. She has been using intermittent catheterization off and on for the last 2 years and admits to being noncompliant with it. Her vital signs in clinic are within normal limits. Her serum creatinine is 0.9 mg/dL. Her UA reveals pyuria with 3–5 WBC/HPF and a urine pH of 7.0. She undergoes a renal ultrasound that shows no abnormalities. Her KUB is shown in Case Fig. 47.4.

1. The next step in management is:
   a. Urinary alkalinization and observation
   b. Exploratory laparotomy and extraction of the stones
   c. Placement of catheter and irrigation with acetohydroxamic acid
   d. ESWL
   e. Conversion of neobladder to ileal conduit

Answers

1. **d.** Conservative management with bowel rest and neobladder decompression with urethral catheter is a good initial strategy in patients with small neobladder-colon fistulas without evidence of distal intestinal obstruction and signs and symptoms of sepsis. Fulguration of the fistula and placement of a colonic stent have not been shown to cause closure of fistulous tracts. Bilateral percutaneous nephrostomy tubes would divert urinary flow, but would not divert fecal flow. Surgical exploration should be attempted in patients who have signs/symptoms of sepsis or peritonitis or in patients who fail conservative measures.
2. **c.** This patient has developed a ureteroenteric stricture (which can occur in 3–8% of patients) with sign and symptoms of sepsis. He will need to undergo urgent decompression of his left kidney with a percutaneous

nephrostomy tube in addition to broad-spectrum IV antibiotics. While placement of a ureteral stent is commonly performed in patients with intact bladders, it is quite difficult to identify the ureteral-enteric orifices within the neobladder. Urethral catheter placement would decompress a ruptured bladder; however, there is no evidence of extravasation of urine on the CT scan. Surgical exploration and ureteral reimplantation would be the best definitive management for ureteroenteric strictures; however, these should be performed in an elective setting.

3. **c.** Reabsorption of ammonium and chloride from the urine in a neobladder can worsen hepatic impairment and can precipitate encephalopathy, and thus hepatic insufficiency is an absolute contraindication for neobladder. Serum creatinine over 2.0 mg/dL is the accepted upper limit for consideration in a neobladder, and thus a creatinine of 1.4 mg/dL is not an absolute contraindication to neobladder diversion. Positive pelvic lymph nodes, history of left hemicolectomy, and history of a TURP are not absolute contraindications for neobladder.
4. **d.** The patient has sustained a neobladder rupture from blunt trauma to his abdomen resulting in urinary ascites. Given that the patient is clinically stable there is no need for exploratory laparotomy. Placement of a urethral catheter and cystogram will drain the neobladder as well as confirm the diagnosis of neobladder rupture and could provide insight into the degree/size of injury. The patient's mechanism and timing of injury does not support bladder neck contracture as the diagnosis usually presents with high post-void residual urine, weak stream, and overflow incontinence. There is no indication for placement of percutaneous nephrostomy tubes.
5. **d.** There is no difference in the stone formation rates between colon or ileal neobladder reservoirs. The remaining answer choices are all associated with stone formation within neobladders.
6. **c.** The image depicts a neobladder to vaginal wall fistula. While care was taken during the initial operation to spare her vagina there was likely an injury to the anterior vaginal wall which resulted in a fistulous connection to the neobladder. Disease recurrence is less likely given the location of the fistula and that her disease was primarily at the bladder dome. Extravasation and displacement of the anastomosis commonly cause bladder neck contractures while an acute neovesical-urethral angle usually results in hypercontinence.
7. **a.** The patient presents with urinary retention secondary to bladder neck contracture and early urosepsis. Bladder neck contracture occurs in 2.4–9% of patients. It is prudent to decompress the neobladder in an expeditious fashion with cystoscopy, dilation, and catheter placement. Once the patient's condition improves, more formal management of the bladder neck contracture can be performed with transurethral incision or resection of scar tissue.
8. **a.** Bladder neck contracture occurs in 2.4–9% of patients with patients presenting with urinary retention and weak stream. A more serious presentation includes neobladder rupture, which requires urgent urinary catheter placement. Causes for bladder neck contracture are myriad, but most commonly result from extravasation of urine after neobladder surgery, which causes inflammation and scarring of the neovesical anastomosis.
9. **e.** The patient has an obstructing 1-cm UPJ stone in the left ureter without signs/symptoms of infection. Retrograde ureteroscopy can be challenging as it is difficult to identify the ureteroeneteric anastomosis orifices. ESWL is an option, but does not have as high stone clearance rates for lower pole stones. PCNL is the preferred management strategy for upper tract stones in patients with a neobladder and has higher stone clearance rates compared to ESWL for lower pole stones.
10. **c.** Absolute contraindication for neobladder include serum Cr >2.0 mg/dL, inflammatory bowel disease (not prior bowel resection), and disease at the bladder neck. Age and mild stress urinary incontinence are not absolute contraindications to neobladder diversion.

CASE 1

1. **e.** The patient has a distended bladder, leukocytosis, and fevers and requires urgent decompression of his neobladder. If the patient was stable, then cystoscopy in OR with transurethral incision of the bladder neck would be a reasonable option with more durable long-term results. Suprapubic tube placement is an option but should only be used if a urethral catheter could not be placed.
2. **d.** The patient has evidence of a neobladder rupture secondary to obstruction from his bladder neck contracture as evidenced by contrast extravasation from the neobladder in the CT scan image. He already has a urethral catheter in place and given that he is hemodynamically stable percutaneous drain placement would be the best option. If the patient was hemodynamically unstable exploratory laparotomy would be the best next step.
3. **b.** The patient has a recurrent bladder neck contracture that recurred despite dilation. The best next step would be to take the patient to the OR and perform an incision of the bladder neck at the 5- and 7-o'clock positions. Open revision of the bladder neck would be quite difficult to perform and would result in poor healing and possible incontinence. Suprapubic tube placement would decompress the neobladder, but would not result in restoring functional voiding to the patient. Repeat dilation of the urethra would likely not be successful given that it failed once already.

CASE 2

1. **b.** This patient has three large stones within her neobladder. Stone formation in the neobladder can occur in a patient with a foreign body, metallic stapes, excess mucus production, and chronic infection. In this case the patient's stones are quite large and will require open or endoscopic removal of the stones.

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48 Complications of Bladder Augmentation and Surgery for Neurogenic Bladder

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CHAPTER OUTLINE

Introduction
Short-term Complications
Long-term Complications
Urinary Tract Infection and Bacteriuria
Stones
Perforation
Carcinoma
Metabolic Disorders
Bowel Dysfunction
Incontinence
Pregnancy
Conclusion
Chapter 48 Questions and Answers

KEY POINTS

1. Bladder augmentation is a safe, well-tolerated, and effective surgery in appropriately selected patients.
2. Prolonged postoperative anastomotic leak, although rare, is a known early complication of bladder augmentation. It can be prevented and ultimately corrected by continuous bladder drainage and regular irrigation with mucus evacuation. Leaks that initially fail conservative therapy may require percutaneous diversion of the upper tract.
3. Stones may be identified in augmented bladders. Regularly removing mucus and appropriately treating urea-splitting organisms in the urine can assist in prevention of stone formation.
4. Perforation of an augmented bladder is a rare but potentially fatal complication. A high degree of suspicion should be maintained for patients with bladder augmentation who become acutely ill. CT cystogram is the optimal study to identify a perforated bladder augment, which requires surgical repair.
5. There is an unclear association between prior bladder augmentation and bladder cancer. Although no standardized guidelines exist for carcinoma surveillance for these patients, annual cystoscopy starting 5 to 10 years after augmentation is recommended. Gross hematuria requires appropriate and timely evaluation in patients who have undergone augmentation.

Introduction

Von Mikulicz first described augmentation of the bladder with the use of an intestinal segment in 1889. It was not until the 1950s, however, that this procedure became more widely used after a report by Couvelaire described augmentation of small, contracted tuberculous bladders. Bladder augmentation is now an accepted technique used to increase bladder capacity.[1] However, with the introduction of onabotulinumtoxinA (BTX) as an effective minimally invasive treatment for overactive bladder in 2000, the overall number of bladder augmentations (also described as augmentation cystoplasty) decreased.[1,2] In the United Kingdom, the number of bladder augmentations decreased from 192 in 2000 to 120 in 2010 and the number performed in the United States decreased by 25% between 2000 and 2009.[1,3] Today, the indications for augmentation cystoplasty (AC) include patients with impaired compliance, small bladder capacity, and refractory detrusor overactivity that have failed behavioral, medication, and intravesical therapies.[4] Although ileum is most commonly used, intestinal segments from the stomach to the colon have been utilized for bladder augmentation.[1]

OnabotulinumtoxinA was initially shown by Shurch et al. in 2000 to improve detrusor overactivity and incontinence in patients with spinal cord injury.[2] Subsequent phase III clinical trials have demonstrated improved urinary incontinence, urodynamic parameters, and quality of life (QOL) in patients with neurogenic bladder.[5,6] These benefits have also been demonstrated in patients with nonneurogenic

overactive bladder.[7] Treatment with BTX requires repeat injections every 3 to 12 months with durable results at 5 years.[8] The most common complications are urinary tract infections (UTIs) and urinary retention. It has been suggested that in patients requiring more frequent injections (<5.1 months), AC may be more cost-effective long term; however, this assumes a low complication rate of less than 14%.[9] Therefore, in patients that fail BTX injections or require frequent injections, AC remains a viable treatment option.

Neuromodulation is another therapeutic option for patients with overactive bladder that have failed conservative and drug therapies and for patients unwilling to take on the risk of intermittent catheterization with BTX. Sacral neuromodulation (SNM) and posterior tibial nerve stimulation (PTNS) are options in patients with nonneurogenic overactive bladder. A 50% improvement is maintained at 5 years in 50% of patients undergoing SNM.[8] Overall continence rates or cure with SNM at 5 years is closer to 15% compared to 80–100% overall continence after bladder augmentation in neurogenic patients and 78–90% in idiopathic detrusor overactivity.[1,8] Overall, it is clear that AC remains a necessary and viable treatment option for overactive bladder despite emerging therapies.

The goal of this chapter is to discuss the presentation and incidence of the various complications seen with AC, techniques to avoid these complications during the initial surgical procedure, and therapies and procedures available to treat the complications. Two distinct populations undergo AC:ß younger patients with neurogenic bladder conditions such as those with spina bifida, and older patients that develop neurogenic bladder conditions later in life, such as after a spinal cord injury or those with small capacity bladders related to radiation or idiopathic causes.

Short-term Complications

Relatively few early complications are specifically related to bladder augmentation surgery. Patients undergoing AC are at risk for cardiovascular, pulmonary, gastrointestinal, and thromboembolic perioperative events as seen with any intraabdominal procedure. A query of the American College of Surgeons National Quality Improvement Program Pediatric Database from 2012–2103 revealed that of the 97 patients that underwent AC alone, 18.6% of patients had a complication within 30 days of the operative procedure. Of these, the most common complications were urinary tract infection (UTI) at 9.3%, followed by wound complications (7.8%) including three superficial infections and one dehiscence. Six patients (6.2%) required transfusion or had a bleeding complication, one patient became septic, and there were eight patients (8.3%) that required reoperation. Reoperations included exploratory laparotomy, cystourethroscopy, revision, and exploration of the intestinal anastomosis. Increased risk of a 30-day event was associated with increased operative time, procedure number, and high surgical risk score. There were no mortalities at 30 days.[10] A mortality rate as high as 2.7% was reported in older literature. The higher mortality rates were also associated with additional surgical procedures. Commonly noted early surgical complications include a 1.9–10.3% risk of bowel obstruction and a risk of a significant wound infection of 6.4%.[11] Bleeding requiring blood transfusion is seen in 3% of patients undergoing AC.[11,12]



Figure 48.1 Cystogram demonstrating an early leak after augmentation ileocystoplasty.

The incidence of early bladder anastomotic leak (Fig. 48.1) after augmentation is extremely low.[13] Two were reported in a series of 133 patients, noted on postoperative days 2 and 5 respectively, and each required surgical exploration and repair.[13] Early leaks are prevented by optimal bladder drainage, which can be achieved with use of both a urethral and a suprapubic catheter. The perivesical space should be well drained. The augmented bladder should be regularly irrigated to evacuate mucus and to minimize the risk of a mucus plug. Mucus plugs can clog a catheter and lead to poor urinary drainage of the newly constructed augment with possible leak at the anastomosis. Small anastomotic leaks that are adequately drained should heal on their own with time. When a trial of conservative therapy fails to heal clinically significant anastomotic leaks, percutaneous drainage of both kidneys and drainage of urinoma, if one is present, are required. Rarely, an ischemic bowel segment can cause anastomotic leak, and in these cases conservative management is not successful. Laparotomy with resection of the nonviable segment and repeat anastomosis are necessary.[4]

Patients with myelomeningocele may be at increased risk for specific complications following AC. The risk of ventriculoperitoneal (VP) shunt infection after AC ranges from 0% to 20%. Appropriate perioperative antibiotics should be given, and any risk of intestinal spillage into the abdominal cavity should be minimized. Urine should be clear of infection preoperatively.[14] Conversion of the VP shunt out of the peritoneal cavity to ventriculopleural shunt can be considered prior to bladder augmentation; however, data regarding this approach are limited.[14] Another technique to guard against shunt infection is the use of the extraperitoneal augment, which allows a significant portion of the

operation to be performed extraperitoneally and thus minimizes exposure of the shunt to potential infection. Symptoms of an infected VP shunt may be vague and mimic partial small bowel obstruction. Other symptoms and signs include fever, headaches, lethargy, change in vision and mental status, and seizures. In addition to significant morbidity, shunt infections are linked to higher risks of future shunt infection and malfunction, intellectual impairment, and even death.[14,15] If shunt infection is suspected, broad-spectrum antibiotics (Vancomycin, frequently in combination with Rifampin) should be instituted and neurosurgical consultation initiated.[15]

Intraoperatively, surgeons should also be able to recognize the signs and symptoms of a latex allergy reaction. This allergy is most commonly seen in patients with myelomeningocele and often manifests as a precipitous drop in blood pressure related to the reaction to the latex in the surgical gloves that are in contact with the intraabdominal contents. Because of the known risk of this potentially life-threatening complication in this patient population, most centers now require surgeons operating on patients with spina bifida to wear nonlatex surgical gloves and to use latex-free catheters and latex-free surgical drains. If a reaction does occur intraoperatively, recommendations include instant interruption of contact with possible antigens (change gloves, surgical drains, and possibly contaminated instruments), copious irrigation of the field, expeditious completion or termination of the surgical procedure, volume expansion, and appropriate resuscitation and management of anaphylaxis by the anesthesia team.

The patient's bladder neck competence should be considered with evaluation for augmentation cystoplasty. If it is found to be incompetent, our preference is to perform a tight fascial bladder neck sling. If the bladder neck is of insufficient length, bladder neck closure may be performed through the abdominal incision for the augmentation cystoplasty. If bladder neck closure is performed, great care must be taken to close in multiple layers, preferably nonoverlapping layers, with interposition such as omentum to prevent fistula formation. The importance of good social support and compliance is magnified in patients with bladder neck closure given the potential mortality associated with the inability to catheterize and a closed bladder neck.[16]

Long-term Complications

Long-term complications of bladder augmentation include bacteriuria/UTIs, metabolic changes, stone formation, perforation of the augmented bladder, bowel dysfunction, incontinence, and the potential risk of tumor formation.[17] A recent study of 2831 bladder augmentations reported a 10-year cumulative incidence of bladder rupture (2.9–6.4%), small bowel obstruction (5.2–10.3%), bladder stones (13.3–36.0%), pyelonephritis (16.1–37.1%), cystolitholapaxy (13.3–35.1%), and re-augmentation (5.2–13.4%).[12]

URINARY TRACT INFECTION AND BACTERIURIA

Bacterial colonization of the urine and asymptomatic bacteriuria is a very common finding in patients with bladder augmentation. Most studies have estimated the incidence to be somewhere between 65% and 100% of patients.[11] The need for intermittent catheterization (IC) certainly predisposes these patients to bacteriuria. Patients undergoing AC for nonneurogenic reasons are more likely to be able to void on their own and therefore have one less risk factor for bacteriuria. Other risk factors for bacteriuria in patients after AC include large residual urine volume and the presence of mucus, which can harbor bacteria.[1,11,18]

Symptomatic UTIs are less common than asymptomatic bacteriuria, with a reported incidence of 4–49%.[19,20] Patients with neurogenic bladder (NGB) may have vague symptoms of UTIs like an increase in spasticity, malodorous or cloudy urine, or symptoms of concomitant autonomic dysreflexia instead of typical symptoms of UTI, such as frequency, urgency, and dysuria. In these cases, obtaining a urine culture and treating based on the culture is appropriate. Because of the lack of clear-cut symptoms, at times it is not always straightforward to determine when antibiotics should be instituted, and in many circumstances asymptomatic patients should be discouraged from treating changes in urine odor and color even if bacteriuria is found on culture. One possible exception to this concept is when urea-splitting organisms are noted on culture. In this case, most clinicians suggest treating bacteria due to the association with renal calculi. A short course of antibiotics of 3–5 days is given. If the patient is symptomatic a longer course of 7–10 days is warranted. Patient education is likely the most important factor in avoiding unnecessary use of antibiotics in this scenario.

Recurrent UTIs can be a significant issue for patients with NGB at baseline before bladder augmentation. It is not always clear whether a postoperative infection in these patients is a continuation of their preoperative bladder disease or whether the infection is the result of the bladder augmentation procedure itself. Nonetheless, despite the need for intermittent catheterization (IC) in patients undergoing bladder augmentation for NGB, these patients have been shown to have fewer instances of postoperative UTI compared with the preoperative state.[21] This finding may be related to secretion of immunoglobulin A by the bowel that prevents bacterial adherence to epithelial cells.[22]

The first step in the management of recurrent symptomatic UTIs is to image the upper and lower urinary tracts to rule out potential sources of infection like stones and foreign bodies. Patients experiencing symptomatic UTIs should be encouraged to irrigate the bladder regularly during IC. This maneuver may help to remove mucus, which may harbor bacteria and make it more difficult to eradicate infections. In addition, patients may benefit from changing IC technique by using single-use catheter kits, though the data supporting this practice are controversial. Similarly, there is little evidence that hydrophilic catheters are helpful in decreasing the risk of recurrent UTI.[23] A recent Cochrane review including 31 different trials regarding IC concluded that there is no convincing evidence that the incidence of UTI is affected by use of aseptic or clean technique, coated or uncoated catheters, single (sterile) or multiple-use (clean) catheters, self-catheterization or catheterization by others, or by any other strategy.[24]

Use of antibiotic irrigations has been advocated to help reduce the incidence of recurrent infections, though data

are lacking. It is our practice to recommend Gentamicin irrigation two to three times weekly for patients who continue to have antibiotics resistant UTI after all other conservative methods fail. Intravesical gentamicin has a low risk of absorption and has been shown to be highly effective. It has prolonged stability without special storage conditions and only severe bladder inflammation can potentially increase transvesical absorption.[25,26]

The use of cranberry supplementation has been shown to have a moderate benefit in the prevention of recurrent symptomatic UTIs in women. Concentrated cranberry supplementation may have a role, and is routinely used, though data relating to clinical practice in the neurogenic subpopulation are lacking.[27]

Suppressive ("prophylactic") antibiotic use has been studied in patients on IC at risk for recurrent UTIs. A recent Cochrane review concluded that for patients on IC, there is limited evidence that receiving prophylactic oral antibiotics reduces the rate of asymptomatic bacteriuria. However, there is weak evidence that use of prophylactic antibiotics can result in a lower incidence of symptomatic bacteriuria. Possible benefits of antibiotic prophylaxis must be balanced against possible adverse effects, such as development of antibiotic-resistant bacteria. These risks cannot be reliably estimated from currently available trials.[28]

STONES

The incidence of stone disease in patients with bladder augmentation using small bowel/large bowel ranges from 10% to 50%[17,29,30] (Fig. 48.2). A higher incidence of stones is noted in patients with continent urinary stomas.[31] Patients with bladder or renal stones have been found to have a 50% chance of recurrence. Of patients with recurrent renal stones, 40% were noninfectious after an initial infectious stone.[32] Compared to patients who are able to void spontaneously, stones are five times more common in patients requiring IC through the native urethra and 10 times more common if IC is performed through a continent urinary diversion stoma.[33] The reason is believed to be secondary to incomplete urinary emptying and urinary stasis that may be seen with this type of reconstruction as well as a higher incidence of bacteriuria in patients who perform IC. Recurrent UTI and concomitant bladder neck surgery also are significant risk factors for stone formation in patients with an augmented bladder.[34,35] Foreign bodies such as exposed staples, usually associated with a continent stoma, can also serve as a nidus of stone formation. A lower incidence of stone formation has been reported in patients with gastrocystoplasty, probably because of lower urinary pH, less mucus production, and a lower incidence of bacteriuria.[36] In a study of children who had undergone AC, bladder stones were found to be most commonly infectious stones with struvite being the most common composition at 55.2%, followed by calcium phosphate (28.7%), and pure carbonate apatite (10.5%). Renal stones were most likely calcium phosphate (46.7%) struvite (36.7%), or pure calcium oxalate (13.3%). Overall, of those with bladder stones, 22.7% also developed renal stones. [32]

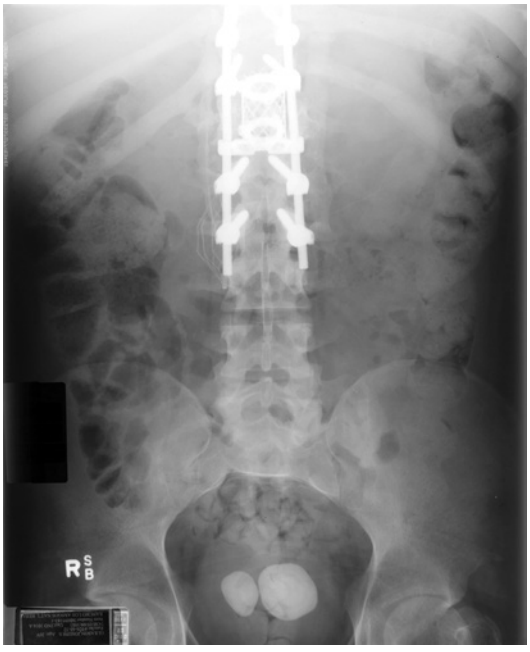


Figure 48.2 Radiographic study of the kidneys, ureters, and bladder. This 45-year-old patient with a T6 spinal cord injury had bladder augmentation 6 years earlier and now has large bladder calculi.

Several groups have studied causes of bladder stone formation. Khoury and colleagues[37] compared the mucus of stone formers with nonstone formers and reported a significantly higher calcium-to-phosphate ($p < 0.05$) ratio in the mucus of the patients who formed stones. This finding suggests that mucus could conceivably be a nidus of stone formation and removal of mucus could minimize future stone formation. Hensle and colleagues[31] investigated a pediatric population after bladder augmentation (with and without stomas) and found a statistically significant reduction (43% vs 7%; $p < 0.001$) in the incidence of stone formation in patients receiving a prophylactic irrigation protocol consisting of 240 mL saline solution and 120–240 mL gentamicin sulfate solution (240–480 mg gentamicin/1 L saline) twice a week.[31] However, use of other mucoregulatory agents (*N*-acetylcysteine, aspirin, urea, ranitidine, and octreotide) to reduce mucus in every patient with augmentation is questionable and is not recommended, as multiple studies including a randomized trial did not show any benefit of routine use of these agents.[38]

Most patients with stones are more likely to be diagnosed during routine radiographic follow-up of their NGB, or perhaps during surveillance cystoscopy. However, common symptoms of stones include hematuria, recurrent UTI, and worsening of incontinence. Treatment of stones is directed at stone removal and can usually be done endoscopically. For large stones, an open or percutaneous procedure may need to be performed. Percutaneous cystolithotomy should be considered in pediatric patients with urethras too small to accommodate standard endoscopic equipment. This consideration is also important in patients who have undergone a prior Mitrofanoff procedure (or other continent stoma such as Monti), which may not allow passage of an endoscope large enough to treat a bladder stone adequately. An Amplatz set can be used to dilate a suprapubic tube tract in preparation for appropriate fragmentation (if needed) with laser or electrohydraulic lithotripsy and removal.[39] It is important to remove all the stone material because any

remaining fragments of stone can serve as a nidus of recurrent stone formation. During any type of endoscopic procedure to remove stones, the potential risk exists of unidentified perforation through the much thinner bowel used to perform bladder augmentation; therefore, a temporary catheter should be left in place postoperatively.

PERFORATION

Perforation is a potentially life-threatening complication following augmentation cystoplasty and is seen in 3–13% of patients[12,13,40–42] Risk factors for perforation of augmentation cystoplasty include a competent bladder outlet that does not allow for a "pop-off" of urine, recurrent UTI, the need to empty the bladder with IC, and chronic overdistention, which is often seen in patients who do not maintain an appropriate IC schedule.[43] Gastrocystoplasty or ileocystoplasty may be associated with lower incidence of spontaneous perforation than other bowel segments.[41,42] Several causes of perforations of the augmented bladder have been evaluated. Bowel ischemia secondary to chronic overdistention and subsequent vascular compromise can lead to rupture.[44] Bowel detubularization, which is essential in eliminating peristaltic waves, has been suggested as a potential source of bowel necrosis and an underlying cause of perforation of the ischemic and necrotic bowel segment.[40] High pressures generated from uninhibited bladder contractions occurring in the augmented bladder also could be the underlying cause of perforation.[44] However, most patients who undergo properly performed bladder augmentation should have a significant and sustained decrease of detrusor pressure to acceptable levels and thus should not be at risk of perforation if an appropriate IC regimen is maintained.[45]

The most common presenting symptom of perforation is acute abdominal pain, though other commonly seen symptoms are nausea, vomiting, oliguria, and fever, as well as shoulder pain secondary to diaphragmatic irritation. Examination should reveal a distended abdomen with peritoneal signs. Patients with NGB may have greater morbidity and mortality associated with perforation because alterations in sensory pathways secondary to their underlying neurologic condition may lead to a delay in recognition. Cystogram may show extravasation; however, ~24% of patients may have normal study results.[13] Because of the lack of initial symptoms in certain NGB patients combined with the potential of a false-negative evaluation, a high degree of suspicion for this injury should be maintained in patients with bladder augmentation who become acutely ill. A CT urogram may be superior to a cystogram in identifying a perforated augmented bladder, although this should not supplant clinical judgment even in the face of a negative study.[43]

Once the diagnosis of bladder perforation is made, patients should receive aggressive intravenous hydration and broad-spectrum antibiotics, and undergo urgent abdominal exploration to repair the injury. The site of perforation is either the junction between the bowel and the bladder wall or the augment segment. Limited reports have described the conservative management of a perforated augmented bladder with catheter drainage of the bladder and percutaneous drainage of any intraabdominal fluid collections. However, because diagnosis of perforation is often delayed in this patient population, conservative management should be reserved for patients who are hemodynamically stable and do not show signs of progression or worsening of their symptoms.[46]

CARCINOMA

The actual risk of cancer in patients with bladder augmentation is not known. However, rates of cancer in patients with an augmented bladder range from 0% to 1.2% at 15 years of follow-up.[11,47] Most tumors are diagnosed within 10 years after the original surgical procedure; however, carcinoma occurring 50 years after AC has been reported as well.[48] Patients undergoing gastrocystoplasty seem to be at higher risk of developing carcinoma.[49,50]

Potential risk factors for tumor formation in bladder augmentation include chronic inflammation of the augment patch, recurrent UTI, and urinary stasis.[51–53] The association of recurrent UTI may be related to the impact of bowel and infection on urinary nitrates that are ultimately converted to nitrosamines. Nitrosamines have been implicated in tumors associated with urinary conduits and ureterosigmoidostomies.[54] Adenocarcinoma is the most commonly identified tumor in augmented bladders and is typically found in the region of the anastomosis of the bowel and bladder;[47] however, transitional cell carcinoma has been reported as well.[47]

A high degree of suspicion must be maintained to make the diagnosis. Patients with an augmented bladder perform regular IC and often have microscopic hematuria of benign origin. However, patients with gross hematuria should undergo prompt cystoscopy. Although no standard guidelines for cystoscopic evaluation and surveillance of these patients exist, a regimen of annual cystoscopy starting after 5 years[55] or 10 years following the augmentation has been proposed.[47] Regular cytologic studies in these patients, to screen for abnormalities, have also been proposed; however, cytologic examination is often unreliable in patients who have undergone AC, secondary to a chronically colonized state.[33]

METABOLIC DISORDERS

Hyperchloremic metabolic acidosis is the most commonly noted metabolic abnormality in patients who have undergone AC with either an ileal or a colonic segment. This finding is secondary to reabsorption of ammonia and ammonium chloride and secretion of bicarbonate by the bowel segment.[20,56] However, symptomatic acidosis requiring oral therapy with bicarbonate has only been reported in 16% of these patients.[11] Treatment of hyperchloremic acidosis consists of administration of alkalizing agents. Prophylactic alkali substitution should be commenced at a base excess below −2.5 mmol/L, with the aim of avoiding the long-term complications of clinically evident acidosis.[57] There is an association between renal insufficiency and an inability to handle excess acid load that leads to symptomatic acidosis in patients undergoing complete urinary reconstruction. Therefore patients with a serum creatinine level above 2.2 mg/dL[58] who require lower urinary tract reconstruction should be advised to undergo conduit rather

than augmentation to minimize the contact time of the urine and bowel.

One potential concern with chronic acidosis is buffering of the acid load by bone, with resulting bone demineralization. This can be a significant issue in children and can potentially affect bone growth. In fact, Mundy and Nurse[59] noted a halving of growth rate in 20% of children undergoing colocystoplasty. Interestingly, a negative impact on linear growth has not been noted in patients undergoing ileocystoplasty.[59,60] The reason for this finding may be that ileum, as opposed to colon, is able to reabsorb calcium. Boylu and colleagues[61] used bone-mineral density to evaluate pediatric patients with and without neurogenic disorders before and after ileocystoplasty. These investigators concluded that any changes in bone-mineral density were related to the underlying neurologic disease and its locomotor consequences. The decrease in bone-mineral density was not thought to be secondary to metabolic changes related to the bladder augmentation.[61]

Gastrocystoplasty can be preferred in patients with underlying renal insufficiency because no additional acid load is generated with augmentation using stomach segment. However, hematuria-dysuria syndrome can occur following gastrocystoplasty. Symptoms include bladder spasms, hematuria, dysuria, and suprapubic or penile pain. This complication has been noted in 26–37% of patients undergoing gastrocystoplasty and is related to irritation of the bladder mucosa from acid produced by the stomach segment used for augmentation. This syndrome can usually be managed with histamine (H_2) blockers.[62,63] Largely due to the high incidence of this syndrome following gastrocystoplasty, this procedure is now only rarely performed.

Vitamin B_{12} deficiency has been reported in adults in whom ileal segments had been used for AC, especially if longer segments (>60 cm) were used.[64] In children, no decrease in vitamin B_{12} levels was observed following bladder augmentation and substitution using ileal segments in most cases after a follow-up period of up to 8 years.[65] However, one study demonstrated an increasing risk of vitamin B_{12} deficiency after the seventh postoperative year when ileal segments had been used.[66] Since large hepatic vitamin B_{12} reserves prevent symptoms of vitamin B_{12} deficiency over a period of 2–5 years even in the presence of severe malabsorption, serum vitamin B_{12} levels should be checked annually starting at year 5 following augmentation. Treatment can be oral and/or intramuscular injection; however, a randomized study demonstrated that oral therapy (2 mg per day) is as effective as parenteral treatment (1 mg intramuscularly).[67]

BOWEL DYSFUNCTION

Chologenic diarrhea due to the loss of bile acids via the large bowel is one potential source of bowel dysfunction following AC. Many of these patients are undergoing cystoplasty for NGB and may have neurogenic bowel dysfunction as well. Other possible causes of bowel dysfunction after AC include colonization of the distal ileum with colonic bacteria after resection of the ileocecal valve, and bile acid malabsorption due to resection of the terminal ileum. This can lead to an increased water and electrolyte load delivered to the colon that cannot be adequately reabsorbed, with resulting diarrhea. In addition, the increased bile acid load can compound the problem by increasing gut motility. Fewer patients with sigmoid augmentation note postoperative bowel dysfunction compared to ileum or ileocecal augments, a finding which appears to strengthen the association of ileal resection with certain types of postoperative bowel disturbances.[68] Despite this association, ileum is much more commonly used since it provides lower reservoir pressures and better compliance than do sigmoid segments.[69]

The overall prevalence of bowel dysfunction after bladder augmentation is not entirely clear from a review of the literature. In a review of 113 patients with 3-year follow-up after cystoplasty, Singh and Thomas[68] noted a persistence of bowel dysfunction in 30% of patients. Complaints included an increase in stool frequency (38%), looser stool consistency (38%), and an increase in episodes of fecal incontinence (23%).[68] Husmann and Cain[70] reviewed 63 patients after a hemi-Indiana augmentation procedure and noted an improvement in fecal continence in 23% of patients, no change in 74%, and worsening of fecal control in 3%. Herschorn and Hewit reviewed 59 patients with a median follow-up of 76 months; 18.6% of patients reported bowel dysfunction, although seven of those 11 patients noted bowel issues preoperatively as well.[71]

Therapy for bowel dysfunction includes a low-fat diet and standard oral antidiarrhea treatment (typically loperamide). Anion exchange resin (cholestyramine) can be used in patients with refractory cases. Since long-term cholestyramine use is associated with poor absorption of fat-soluble vitamins A, D, and K, vitamin levels should be checked regularly. Despite active treatment, bowel dysfunction persists in a significant portion of these patients. Careful counseling and evaluation of bowel function before surgical intervention may decrease the impact on patients' satisfaction postoperatively.

INCONTINENCE

Persistent urinary incontinence after AC can result from several issues. Leakage that only occurs at night is often of multifactorial origin. Potential causes include decreased urethral resting pressure, nocturnal polyuria, and failure of the sphincter to increase its resting tone in response to bladder contractions. Failure to diagnose an incompetent outlet preoperatively can lead to symptoms of stress urinary incontinence. For patients with NGB who use a wheelchair, this complication is often noted with complaints of leakage of urine during transfers or pressure release. Patients may also leak secondary to inadequate bladder augmentation. This complication could result from the use of an inadequately short piece of intestine, an impaired blood supply to the augment segment, either of which can lead to decreased capacity or compliance, or the presence of bowel mass contractions.

Evaluation of persistent urinary incontinence after bladder augmentation typically includes completion of a voiding diary and urodynamics. Voiding diaries can be very helpful in identifying potential reversible causes such as excessive fluid intake and patients who perform IC too infrequently. If the voiding diary is unremarkable, urodynamic studies allow for evaluation of the bladder and the outlet to ascertain the cause of the urinary leakage. Therapy can

then be directed accordingly. Potential therapies for an inadequate sphincter include pubovaginal sling, bladder neck reconstruction, bladder neck closure, and artificial urinary sphincter. A study of 11 such patients with follow-up of at least 45 months revealed that insertion of bladder neck artificial urinary sphincter cuff alone was enough to achieve continence in eight (73%) patients.[72]

Simultaneous outlet procedures may be performed at the time of bladder augmentation in the setting of low valsalva leak point pressure or in those with neurogenic incontinence not expected to void spontaneously postoperatively.[73] In a large pediatric cohort of 2831 patients, 16.8 % underwent simultaneous bladder neck surgery.[12] In a cohort of patients undergoing simultaneous bladder neck sling, 88% achieved complete passive urinary continence for 4–6 daytime hours and 6–8 nighttime hours, as well as no stress urinary incontinence. Complications included two wound dehiscences that were subsequently closed. Bladder neck slings are generally safe and effective in well-selected patients.[73] In a series investigating AC and artificial urinary sphincter placement, there were a total of 195 sphincters placed with 35% failing from infection, 5% from tissue atrophy, and 25% from mechanical failure. Significant complications were found in 7% of patients including pelvic abscess, rectal perforation, deep venous thromboembolism, acute urinary retention, urethral strictures and pseudomembranous colitis. The risk of sphincter infection was increased by simultaneous augmentation.[74]

If the bladder was not adequately augmented with the initial procedure, an anticholinergic can be considered. Botulinum toxin has also been used with considerable success in patients with high-pressure NGB, although the use of this agent in patients with treatment failure after bladder augmentation has not been described.[75] If this approach does not resolve the problem, repeat AC with ileum was reported to be successful in five patients in whom prior AC with either stomach or colon failed.[76]

PREGNANCY

A potential issue in young women undergoing bladder augmentation is future pregnancy, including management of the delivery. The most common complication of pregnancy after AC is UTI or pyelonephritis. Other possible issues include premature labor, renal deterioration, and ureteral obstruction.[77] In a review of 15 patients with bladder augmentation, Hill and Kramer[78] reported development of pyelonephritis in 60% and premature labor in 25% of patients. Therefore frequent urinalysis needs to be performed and infections need to be treated early and aggressively.

No consensus exists on whether delivery should be done by a vaginal or cesarean approach in patients with an augmented bladder. Hill and Kramer[78] recommended proceeding with standard vaginal delivery in patients who had undergone AC alone. In patients who had undergone a concomitant procedure for the outlet, the investigators recommended proceeding with cesarean section to minimize potential disruption to the continence mechanism. However, other investigators did not find this to be an issue and reported vaginal delivery to be safe for all patients who had prior AC, even those with prior bladder neck reconstruction.[79,80] If cesarean section is considered, the obstetrician must understand the anatomy of the reconstruction (including the segment utilized) and should have a urologist available for intraoperative consultation.

Conclusions

Bladder augmentation remains a viable alternative for patients with small capacity bladders and refractory overactive bladder and those with impaired compliance, when more conservative strategies have failed. Still, 5–42% of patients will require reoperation following augmentation cystoplasty, and 28% of patients will experience a complication within 30 days of the procedure including UTIs, wound complications, small bowel obstruction, and transfusion.[1,10] Fairly common long-term complications include symptomatic UTIs and bladder or renal stones. And while uncommon, bladder perforation and carcinoma may also occur, and thus patients require lifelong urologic surveillance following augmentation cystoplasty.

References

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Chapter 48 Questions

1. Which of the following is a correct statement regarding augmentation cystoplasty?
   a. The possibility of requiring intermittent catheterization (IC) is much higher in necturus gallbladder (NGB) than with idiopathic conditions
   b. Stone disease is the most common complication
   c. Most perforations can be managed conservatively
   d. Gastrocystoplasty results in hyperchloremic metabolic acidosis
   e. Most bladder tumors following augmentation cystoplasty are seen within 5 years

2. Which of the following is not correct about recurrent urinary tract infection (UTI) after augmentation cystoplasty?
   a. Incidence of bacteremia ranges from 65% to 100% after augmentation
   b. NGB patients may not present with typical symptoms of UTI
   c. There is strong evidence that using a sterile catheter reduces the risk of recurrent UTI
   d. Gram-negative bacteria are the most common organisms
   e. Gentamicin irrigation of the bladder is safe and may be effective in preventing recurrent UTI

3. Which electrolyte abnormality is typically not seen following an ileocystoplasty?
   a. Hyponatremia
   b. Hyperchloremia
   c. Hypokalemia
   d. Hyperkalemia
   e. Hypovitaminosis B_{12}

4. Which of the following mucoregulatory agent has been shown to be effective in reducing stone formation in the bladder augmented with an intestinal segment?
   a. *N*-acetylcysteine
   b. Aspirin
   c. Urea
   d. Ranitidine
   e. None of the above

5. What is the most common short-term complication after bladder augmentation?
   a. Small bowel obstruction
   b. Wound infection
   c. Urinary tract infection
   d. Augment perforation
   e. Transfusion

6. Which recent therapeutic intervention has had the greatest impact on decreasing the rate of bladder augmentations performed?
   a. Percutaneous tibial nerve stimulation
   b. OnabotulinumtoxinA
   c. Intermittent catheterization
   d. Auto augmentation
   e. Sacroneuromodulation

7. What techniques do NOT help decrease the risk of ventriculoperitoneal shunt infections at the time of bladder augmentation?
   a. Urine sterilization
   b. Extraperitoneal bladder augmentation
   c. Conversion to extraperitoneal shunt
   d. Bowel preparation
   e. Manipulation of the ventriculoperitoneal shunt (VPS) intraoperatively

8. What is the most common sign of latex allergy intraoperatively?
   a. Tachycardia
   b. Hyperthermia
   c. Precipitous hypotension
   d. Rash
   e. Bleeding

9. Which segment of bowel is associated with hematuria-dysuria syndrome?
   a. Stomach
   b. Ileum
   c. Sigmoid
   d. Jejunum
   e. Cecum

10. What is the most common carcinoma found after bladder augmentation?
    a. Urothelial carcinoma
    b. Adenocarcinoma
    c. Squamous cell carcinoma
    d. Renal cell carcinoma
    e. Small cell carcinoma

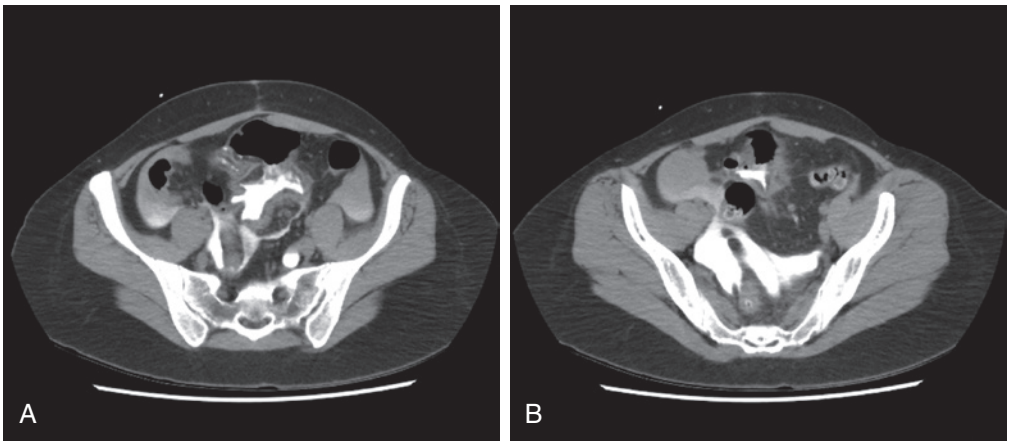
Case Studies

CASE 1

A 33-year-old woman with history of prior Indiana pouch 3 years earlier presents with acute abdominal pain and peritoneal signs after failing to catheterize her pouch for 12 hours. CT cystogram images (Case Fig. 48.1) are shown. Note intraperitoneal contrast. Similar radiographic findings would be noted with leak following augmentation.

1. Which of the following is NOT a risk factor for bladder augmentation perforation?
   a. Competent bladder outlet
   b. Inconsistent intermittent catheterization
   c. Recurrent UTIs
   d. Spontaneous voiding
   e. None of the above

2. Of the following bowel segments used for augmentation, which segment has the lowest rate of perforation?
   a. Sigmoid colon
   b. Transverse colon
   c. Ileum
   d. Jujenum
   e. None of the above



Case Figure 48.1

3. She presents to the emergency room 20 years after her pouch surgery with acute abdominal pain, oliguria and emesis. Peritoneal signs are documented on physical exam. The CT cystogram performed does not reveal a leak. What is the next best step?
   a. Perform a routine cystogram with emptying images
   b. Admit for observation and start broad spectrum IV antibiotics for possible "pouchitis"
   c. Admit for observation, place indwelling catheter and start broad spectrum IV antibiotics pending culture results
   d. Exploratory laparotomy
   e. Place bilateral nephrostomy tubes to divert urine away from pouch and start on broad spectrum IV antibiotics

CASE 2

A 25-year-old female with spina bifida underwent augmentation cystoplasty at age 8 and presents to the clinic for the first time as an adult. She reports no incontinence, but intermittent hematuria for the last year and a strong odor to her urine. Renal ultrasound and a kidney, ureters, and bladder investigation were performed demonstrating multiple bladder stones. She underwent open cystolithotomy. See Case Fig. 48.2.

1. After bladder augmentation, which patient is at lowest risk for bladder stones?
   a. Patient catheterizing via abdominal stoma.
   b. Patient with bladder augmentation and pubovaginal sling on intermittent catheterization
   c. Patient voiding spontaneously with low post-void residuals
   d. Patient with large volume of mucus requiring regular irrigations
   e. Patient with recurrent UTIs

2. What is the most common composition of bladder stones after bladder augmentation?
   a. Calcium phosphate
   b. Calcium oxalate
   c. Struvite
   d. Uric acid
   e. Pure carbonic apatite



Case Figure 48.2

3. What is the most common composition of renal stones after bladder augmentation?
   a. Calcium phosphate
   b. Calcium oxalate
   c. Struvite
   d. Uric acid
   e. Pure carbonic apatite

Answers

1. **a.** IC rates vary from 26% to 100%, generally increase with time, and are higher in the NGB of patients. Greenwell et al. reported a 60% IC rate in NGB compared with 6% in idiopathic patients.[11]
2. **c.** A recent Cochrane review including 31 different trials regarding IC concluded that there is no convincing evidence that the incidence of UTI is affected by use of aseptic or clean technique, coated or uncoated catheters, single (sterile) or multiple-use (clean) catheters,

self-catheterization or catheterization by others, or by any other strategy.[23]

3. **a.** Hyperchloremic metabolic acidosis is the most commonly noted metabolic. Hyponatremia is seen with jejunal augment.
4. **e.** Use of mucoregulatory agents (*N*-acetylcysteine, aspirin, urea, ranitidine, and octreotide) to reduce mucus in every patient with augmentation is questionable and is not recommended, as multiple studies including a randomized trial didn't show any benefit of routine use of these agents.[36]
5. **c.** Urinary tract infections are the most common short-term complication after augmentation.
6. **b.** OnabotulinumtoxinA has decreased the rate of bladder augmentation since 2000.
7. **e.** Minimal contact with the VPS intraoperatively is recommended to avoid contamination.
8. **c.** Latex allergy is common in the neurogenic population and practitioners should have a high index of suspicion and take precautions to prevent this potentially life-threatening complication.
9. **a.** This complication has been noted in 26–37% of patients undergoing gastrocystoplasty and is related to irritation of the bladder mucosa from acid produced by the stomach segment used for augmentation.
10. **b.** Adenocarcinoma is the most commonly identified tumor in augmented bladders and is typically found in the region of the anastomosis of the bowel and bladder; however, transitional cell carcinoma has been reported as well.

CASE 1

1. **d.** Patients with a competent bladder outlet requiring intermittent catheterization are at increased risk of perforation, especially in the setting of recurrent UTIs and poor catheterization compliance.
2. **c.** Gastroplasty and ileoplasty are associated with lower rates of spontaneous perforation than are other segments of bowel or ureteral augmentation.
3. **d.** Twenty-four percent of patients with a perforation will have a negative cystogram; therefore patients require a high index of suspicion for perforation. Treatment is exploration in the OR with maximal drainage of the bladder and peritoneum.

CASE 2

1. **c.** Risk factors for bladder stones include recurrent UTIs and incomplete emptying secondary to outlet procedures or catheterizable channel, as well as large-volume mucus. Patients able to void spontaneously with good emptying have a lower risk of infection and subsequent stones.
2. **c.** Infectious stones are the most common type of bladder stones following bladder augmentation with struvite the most common composition.
3. **a.** Calcium phosphate is the most common type of renal stone after bladder augmentation.

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49 Complications of Female Incontinence Surgery

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CHAPTER OUTLINE

Types of Incontinence
Types of Incontinence Operations
Stress Incontinence Operations
Urge Incontinence Operations
Prevention of Complications
Complications
Choice of Approach
Risk Factors
Complications Related to Stress Urinary Incontinence Surgery
Intraoperative Complications
Urinary Tract Injury
Postoperative Complications
Urethral Bulking Agents
Complications Related to Urge Incontinence Surgery
Botulinum Toxin A
Sacral Neuromodulation
Conclusions
Chapter 49 Questions and Answers

KEY POINTS

1. The popularity of midurethral polypropylene slings has changed the types of complications commonly seen in surgical treatment of stress urinary incontinence (SUI).
2. Intraoperative trocar injury to the bladder during midurethral sling placement is not uncommon, and replacement of the trocar can be accomplished with minimal morbidity.
3. Currently, few or no data on overall complications support one choice of midurethral slings over another (i.e., retropubic vs transobturator) as causing less morbidity; however, some of the complications reported with each of these procedures are unique to that approach.
4. In comparing midurethral slings, obstructive complications are more common with retropubic slings while neuromuscular complications are more likely in the transobturator approach.
5. New voiding symptoms including overactive bladder symptoms or recurrent urinary tract infections (UTIs) following SUI surgical procedures may indicate iatrogenic bladder outlet obstruction (BOO), which is a very difficult and subtle diagnosis in many patients.
6. Attention to technique, experience of the surgeon, and careful endoscopic examination of the urinary tract following anti-UI surgical procedures are important factors in reducing perioperative and postoperative complications.
7. Intradetrusor botulinum toxin injections and sacral neuromodulation have become the mainstay for treatment of refractory overactive bladder and urgency urinary incontinence.

Stress urinary incontinence (SUI) affects 4–10% of women per year with an estimated prevalence of up to 50% of adult women.[1] *Urinary incontinence* (UI) is defined as the complaint of involuntary leakage of urine.[2] Patients with UI may have numerous related problems including depression as a result of the perceived lack of self-control, loss of independence, and lack of self-esteem, and they often curtail their activities for fear of an "accident."[3,4] UI and related overactive bladder may also have serious medical and economic ramifications for untreated or undertreated patients, including perineal dermatitis, worsening of pressure ulcers, urinary tract infections (UTIs), and falls.[5] For these reasons, many individuals suffering from this condition seek treatment. Surgery plays a major role in the therapy of some types of UI. Surgical procedures for UI are some of the most commonly performed operations in the United States by urologists. Thus, understanding how to avoid, and when necessary how to treat, complications related to these surgical procedures is important.

Types of Incontinence

Simply stated, UI may result from abnormalities of the urethra (including the bladder outlet and urinary sphincter), or the bladder, or may be caused by a combination of abnormalities of both structures (Table 49.1).[6] Abnormalities may result in underactivity or overactivity of the urethra or bladder with the subsequent development of UI.

Urethral underactivity results in stress UI (SUI). *Urodynamic SUI* is the involuntary leakage of urine associated

Table 49.1 Functional Classification of Urinary Incontinence

Abnormality	Type of Clinical Incontinence
Bladder overactivity	Urge
Bladder underactivity	Overflow
Urethra overactivity	Overflow
Urethra underactivity	Stress

with an increase in intraabdominal pressure in the absence of a detrusor contraction.[2]

Surgical correction of female SUI is directed toward either of the following: (1) repositioning the urethra or creating a backboard of support or otherwise stabilizing the urethra and bladder neck in a well-supported retropubic position that is receptive to changes in intraabdominal pressure (i.e., sling), or (2) creating coaptation or compression or otherwise augmenting the urethral closure forces provided by the intrinsic sphincteric unit (i.e., periurethral injectables) that affect urethral and bladder neck support.

Urgency UI is the involuntary leakage of urine associated with the symptom of urgency, defined as a sudden compelling desire to void that is difficult to defer.[2] This disorder is generally attributed to detrusor overactivity, as shown by urodynamic assessment. Both phasic bladder overactivity (involuntary bladder contractions) and tonic overactivity (decreased compliance) can contribute to UI. Careful urodynamic evaluation may be necessary in these patients to ascertain lower urinary tract physiology, to assess the risk of deterioration to the upper urinary tract, and to search for coexisting urethral or sphincteric UI.

Most of these patients are treated with a combination of behavioral modification, pelvic floor physical therapy, and oral pharmacologic agents. However, for patients with refractory conditions, the goal of surgical intervention is either to reduce or abolish bladder overactivity and the sensation of urgency or to provide a reservoir of adequate size for the low-pressure storage of adequate volumes of urine.

Types of Incontinence Operations

Except in unusual circumstances, the surgical repair of UI is elective. The decision to treat *symptomatic* UI surgically should be based primarily on the premise that the degree of bother or lifestyle compromise to the patient is sufficient to warrant an *elective* operation and that nonoperative therapy is either undesired or has been ineffective. Therefore, it is particularly troublesome to both the surgeon and the patient when complications arise during or after performance of these elective procedures. In some instances, these complications may be life threatening or may considerably worsen symptoms or quality of life. Thus, the surgeon should clearly describe and counsel patients regarding potential complications preoperatively. Fortunately, however, complications of the surgical treatment of UI are uncommon and when they occur are often amenable to treatment.

Table 49.2 Goals of Surgical Options for Stress Urinary Incontinence

Surgical Option	Goal
Anterior repair	Repositioned urethra or "plicated" sphincter
Retropubic approach Marshall-Marchetti-Krantz vesicourethropexy Burch colposuspension	Repositioned or stabilized urethra or creation of a "backboard" of support for urethral compression during increased intraabdominal pressure
Vaginal needle suspension Stamey Raz	Same as retropubic approach with avoidance of a large abdominal incision and associated morbidity
Sling	
Autologous, cadaveric, synthetic, vaginal wall, etc.	Same as retropubic approach with or without direct urethral coaptation or compression
Tension-free vaginal tape and other polypropylene midurethral slings	Dynamic midurethral support
Artificial urinary sphincter	Intermittent, dynamic urethral coaptation and compression
Bulk agents (injectables)	Improved urethral coaptation

STRESS INCONTINENCE OPERATIONS

The goal of surgical treatment of SUI is to augment urethral closure forces to prevent the egress of urine from the urethra during periods of increased abdominal pressure while at the same time preserving voluntary, low-pressure, and complete bladder emptying. This treatment may involve the use of retropubic or transvaginal suburethral support or compression (slings), periurethral injection (e.g., collagen), or circumferential compression (artificial genitourinary sphincter) (Table 49.2). The precise manner in which each operative procedure improves urethral closure forces and thereby restores urinary continence is not well understood. Nonetheless, >100 different operations have been designed to treat female SUI.

For many years, the transabdominal approach to vesicourethropexy including procedures such as the Marshall-Marchetti-Krantz (MMK) vesicourethropexy and the Burch colposuspension were very popular interventions for female SUI. The goal of these procedures is to elevate or, in some cases, simply prevent rotational descent of the urethra and bladder neck by securing the paraurethral or paravesical fascia to a fixed retropubic structure. Additionally, these procedures may also provide a stable "backboard" on which the urethra and bladder neck are compressed during increases in intraabdominal pressure.

The transvaginal or "needle" suspension procedures were proposed as alternatives to the retropubic operations for urethral UI resulting from vesicourethral hypermobility. These techniques have largely fallen out of favor, especially following a comprehensive meta-analysis published in 1997 suggesting that these procedures were less durable in the long term as compared with slings and retropubic suspensions.[7] A subsequent American Urological Association (AUA) guideline document did not even include these procedures in the update as there were no new publications on

their utilization.[8] Therefore such procedures will not be further discussed in this chapter.

Bone-anchoring techniques emerged as an alternative method of suture fixation for both transvaginal needle suspensions and some types of slings in the 1990s. Numerous proprietary fixation systems had been developed including transvaginal and suprapubic delivery bone-anchoring systems, all of which deliver a suture secured to a metallic screw into the cortical bone of the pubic rami on either side of the midline. The initial enthusiasm for these adjunctive procedures was somewhat dampened by the lack of a demonstrable long-term durable benefit over other techniques as well as the cost and potential associated morbidity, including osteomyelitis and osteitis pubis. Bone-anchoring techniques have largely fallen out of favor.[9–11]

Pubovaginal sling surgery was originally described more than 100 years ago. Fascial slings are generally placed at the level of the bladder neck and proximal third of the urethra and use either autologous tissue harvested from the patient intraoperatively (e.g., anterior rectus sheath, fascia lata) or xenograft or allograft fascia. The fascia may be full length (extending from the abdominal wall through the retropubic space, under the urethra, and back up to the abdominal wall) or rectangular (extending into the retropubic space on either side but secured to the anterior abdominal wall with sutures attached to either end of the sling) (Fig. 49.1).

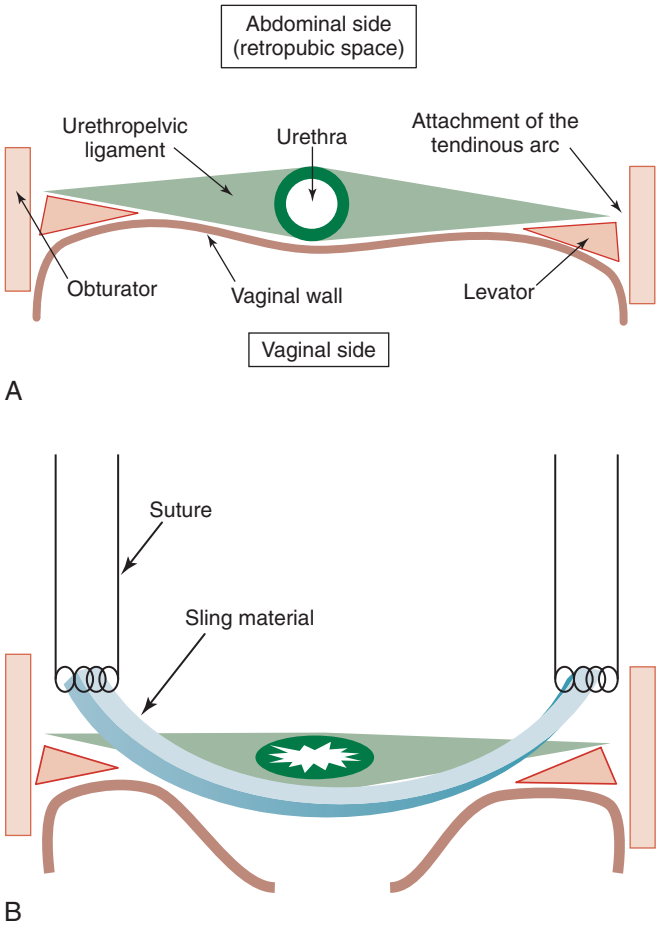


Figure 49.1 Diagrams of the vaginal anatomy in a coronal plane before (A) and after (B) placement of a fascial sling.

The midurethral polypropylene sling (MUS) has become the most common type of sling procedure performed in the United States.[12] This popularity is likely the result of the low morbidity, technical ease, and speed of the procedure; its long-term durability and safety; and the rapid recovery and convalescence. These slings, of which many proprietary types are available, are similar in the completely tension-free, minimally invasive technique in which they are placed under the midurethra. Depending on the choice of device, these slings may be placed through a transvaginal incision utilizing either a suprapubic or transobturator approach. US Food and Drug Administration (FDA) notifications regarding transvaginal mesh placement surfaced in 2008 and 2011. In October 2008, the FDA issued a Public Health Notification regarding the use of transvaginal mesh for pelvic organ prolapse (POP) and SUI,[13] and in July 2011, the FDA released a Safety Communication on serious complications associated with transvaginal mesh for POP but not SUI.[14] The implications of these FDA statements were quite broad including medico-legal ramifications and ongoing nationwide litigation. As the FDA continues its literature review of transvaginal mesh for the treatment of SUI it has reiterated that the standard polypropylene mesh MUS is safe and effective in the treatment of SUI.[15] Despite the FDA statements, it is important to recognize that there has not been a mandatory FDA recall of any transvaginal mesh product. As a result of many converging and complex factors, several mesh manufacturers have voluntarily withdrawn some or all of their POP and/or SUI mesh products but this was not due to a product recall by the FDA.

Periurethral injectable agents have been used for the treatment of SUI in women for decades. Most periurethral agents are injected in a retrograde fashion under direct cystoscopic guidance as an office-based procedure. The exact means by which periurethral injectable agents exert their favorable effects on continence has not been well defined, although an obstructive mechanism or an improved "seal" effect has been suggested.[16] Furthermore, the eventual mechanism of failure for most of these agents is not well understood, although it is believed that biologic reabsorption, particle migration, and ongoing degeneration of the sphincteric apparatus may be contributing factors. Generally, these agents are safe and have good initial efficacy but lack long-term durability.

The artificial urinary sphincter is used in some centers as primary therapy for female SUI. However, in the United States, this device is only very infrequently used in female patients.

URGE INCONTINENCE OPERATIONS

Sacral neuromodulation, intradetrusor injection of botulinum toxin, and augmentation enterocystoplasty have been used for individuals undergoing surgical treatment of urgency UI. Sacral neuromodulation has been used since the 1980s but was finally approved by the FDA for use in the United States in 1997 as a therapy for urinary frequency, urgency, and urge UI. A staged implantation technique or an office-based peripheral nerve evaluation is the initial step in sacral neuromodulation. In either case a good response leads to implantation of a permanent implantable

pulse generator and neurostimulator lead electrode. Low-frequency stimulation of the S3 nerve root results in modulation of neural activity in the lower urinary tract and pelvic floor. The exact mechanism by which sacral neuromodulation exerts its therapeutic effects remains unclear.

In 2011 the FDA approved intradetrusor injection of botulinum toxin A (BT) for the treatment of refractory neurogenic detrusor overactivity, and in 2013 the FDA approved its use for refractory idiopathic detrusor overactivity.[17] BT is produced by the bacterium *Clostridium botulinum* and is the most potent biologic neurotoxin known. The current approved dose for idiopathic detrusor overactivity is 100 units, and for neurogenic detrusor overactivity the approved dose is 200 units. The toxin is injected into the detrusor muscle through the cystoscope with a long, fine needle in a series of 20–30 injections. This treatment is most commonly performed using local anesthesia as an office-based procedure.

BT is thought to produce its efferent motor paralytic effects by inhibiting acetylcholine release at the presynaptic cholinergic neuromuscular junction by cleaving SNAP-25, an intracytoplasmic protein, which blocks the binding and fusion of the synaptic vesicles to the presynaptic membrane terminal. This prevents release of acetylcholine as well as a variety of other neurotransmitters and neuropeptides into the synapse. Clinically this results in muscle weakness, diminished contractility, and muscle atrophy at affected sites some 3–14 days following injection. The effect is reversible in 3 to 12 months, but the mechanism by which smooth muscle regains contractility over time is not well understood and is not fully explained by axonal sprouting. The mechanism of action of BT in reducing urinary urgency may also involve modulating some aspects of the afferent limb of the micturition reflex as well.[18]

Although there is sparse literature available, it appears that augmentation enterocystoplasty as a treatment for urgency incontinence has become less utilized with the increasing widespread use of BT and neuromodulation.[19] Further discussion and complications related to the use of intestine in the urinary tract are reviewed elsewhere in this textbook and are not considered further here (see Chapter 48).

Prevention of Complications

Although most complications related to the surgical treatment of female UI are treatable and generally reversible, the optimal situation is to prevent or minimize the potential for an adverse outcome. This process begins in the preoperative period and is initiated during the diagnostic evaluation and workup. Many factors should be considered in determining the optimal surgical therapy for the patient with UI. These include the origin and type of UI, bladder capacity, renal function, sexual function, medical comorbidities, severity of the leakage, the presence of associated conditions such as vaginal prolapse or concurrent abdominal or pelvic disease requiring surgical correction, prior abdominal and pelvic surgical procedures, and finally the patient's suitability for and willingness to accept the risks of surgery. All these factors may affect both the choice of surgical treatment and the risk of surgical complications.

The proper choice of candidate for an anti-UI operation cannot be overemphasized. One study found the most common reason cited for failure of the previous operation was poor surgical technique, and the next most common reason was the wrong surgical indication.[20] Both of these factors certainly can be addressed and minimized preoperatively. The diagnosis of SUI must be firmly established to propose outlet-enhancing surgery for the treatment of SUI. Other diagnoses that may mimic SUI should be definitively eliminated including fistula, ureteral ectopy, bladder calculi, urethral diverticula, and overflow UI. Overflow UI, in particular secondary to a neurogenic or myogenic disorder, can be mistaken for SUI and this misdiagnosis can lead to inappropriate intervention and surgical treatment failure. The patient's history should be consistent with and confirmed by findings on physical examination and, when appropriate, radiographic or urodynamic testing.

Reversible factors should be addressed. For patients with postmenopausal, hypoestrogenic vaginal atrophy, topical estrogen replacement may reduce the incidence of postoperative vaginal wound dehiscence or extrusion of sling material.[21] UTI and genital tract infection (e.g., candidiasis) should also be treated before surgical intervention. Nutritional disorders should be assessed and corrected preoperatively before elective surgical treatment is performed. Finally, treatment of any medical comorbidities (e.g., diabetic control, hypertension) should be optimized.

Another preoperative factor associated with risk of complications is operative experience with a given procedure.[22,23] The "learning curve" for "simple" procedures such as midurethral slings should not be underestimated and the number of cases performed may correlate with risk of complications.[24,25]

Complications

The field of SUI surgery has advanced rapidly. As noted previously, the types of procedures performed have evolved from transvaginal needle suspensions and retropubic suspensions to various types of slings, most commonly the midurethral polypropylene slings. This shift has implications for the types of complications seen in contemporary practice as compared with complications seen even a few short years ago. Therefore the majority of the discussion that follows concerns the midurethral slings.

CHOICE OF APPROACH

The relative risks of each complication among various types of surgical procedure, especially within a single category such as midurethral slings, are impossible to determine because of the limited amount of randomized controlled trials comparing procedures and approaches. Currently, no published literature provides sufficient evidence to recommend one procedure or approach absolutely over another based only on complication rates. However, it is important to recognize that some types of complications are unique or more likely to occur with one procedure as compared to another. For example, in a randomized controlled trial (RCT), Albo and colleagues[26] compared Burch colposuspension with pubovaginal sling and in this trial

the investigators found that the risks of urinary tract infections, voiding dysfunction, and postoperative urge incontinence were greater in the women who underwent sling procedure but the risk of incidental cystotomy was greater in the Burch group. Comparing results within a single category, the 2010 TOMUS RCT compared the outcomes of retropubic and transobturator midurethral slings.[27] There was a higher rate of voiding dysfunction requiring surgery in the retropubic group, but neurologic symptoms were greater in the transobturator group. These findings have been confirmed by several additional studies and documented in a 2015 Cochrane review on midurethral slings.[28]

RISK FACTORS

Identifying preoperative risk factors such as age, obesity, prior surgical treatment, and impaired contractility that consistently predict for intraoperative and postoperative complications has also been difficult. Most of the data available in the literature are from retrospective studies. In regard to vaginal mesh exposure, one study of 1439 women found that older age, diabetes mellitus, smoking, vaginal incision >2 cm, and recurrent vaginal incisions increase the risk of vaginal mesh exposure.[29,30] Some investigators have found that prior surgical treatment is a predictor of intraoperative bladder injury.[22,23,31] This may be related to the type of prior SUI surgical treatment: Prior retropubic procedures such as Burch or MMK may lead to retropubic scarring and a risk of bladder injury,[31] whereas a prior transvaginal operation such as a Kelly plication, in which the retropubic space is not violated, may not. While there is no standard to evaluate and ascertain which patients will have postoperative voiding dysfunction, it is reasonable to speculate that women with preoperative voiding dysfunction (emptying phase dysfunction) will have a higher risk of postoperative voiding dysfunction and urinary retention.[22]

COMPLICATIONS RELATED TO STRESS URINARY INCONTINENCE SURGERY

Intraoperative Complications

Bleeding. The risk of blood loss greater than 200 mL during SUI surgery is small. The incidence ranges from 0.22% to 8%, with autologous fascial sling associated with the greatest risk[8] and transobturator midurethral sling associated with the least risk of substantial bleeding.[8,32] The risk of blood transfusion ranges from 0.6% to 9% with a reported risk of only 0.6–2% in midurethral slings and 7–9% in Burch suspensions.[8,22]

The risk of bleeding during surgical treatment of SUI can be minimized, but not entirely eliminated, by good operative technique. Multiple blood vessels traverse the deep pelvis including large venous channels in the retropubic space. Named vessels in the obturator fossa, along the pelvic sidewall including the iliac vessels, and within the vascular pedicle of the bladder are at risk for injury, especially during vaginal surgical treatment of UI, because of the lack of direct visualization of these structures during passage of trocars or needles. Major vascular injury can quickly lead to life-threatening hemorrhage if it is not recognized intraoperatively and may result in large retropubic hematomas postoperatively.[33,34]

Bleeding during retropubic bladder neck suspension is usually easily visualized and controlled with a combination of cautery, suture ligature, and, if necessary, direct compression. Occasionally, sponge sticks and readjustment of the retractors may be needed to visualize the bleeding vessels optimally. The retropubic anatomy is very familiar to most urologic surgeons, and bleeding during these procedures is rarely problematic.

In contrast to bleeding during retropubic surgical procedures, bleeding during transvaginal operations can be more problematic at times and more difficult to control. The initial dissection of the vaginal wall from the underlying fascia should be associated with minimal bleeding. Bleeding encountered during this early dissection may indicate an excessively deep and incorrect surgical plane within the wall of the bladder or urethra. In this circumstance, immediate recognition and reevaluation are necessary to avoid inadvertent entry into the urinary tract and to minimize bleeding. Following identification of this situation, dissection should then proceed in the proper surgical plane, which, in reoperative surgical procedures, may be difficult to identify.

Another common site of bleeding during transvaginal SUI surgical procedures occurs when the endopelvic fascia is traversed. Entry into the retropubic space from the transvaginal side or placement of the suprapubic needles or trocars from the abdominal side may be associated with copious bleeding as the endopelvic fascia is perforated. Again, knowledge of the anatomic features, careful attention to technique, maintenance of countertraction, and proper positioning of the perforating scissors (with the tips curved away from the bladder) or trocar in three planes minimize most bleeding (Fig. 49.2). An initial gush of venous bleeding is not unusual during this maneuver, and, although it may be unsettling to the operating surgeon, the bleeding dissipates quickly without further manipulation.

If the bleeding continues and is brisk, the vagina can be packed. It can be very helpful to elevate the anterior vaginal wall manually and compress it anteriorly directly against the posterior symphysis pubis for several minutes using the surgeon's hand, a sponge stick, or a retractor. These maneuvers effectively tamponade bleeding in the retropubic space. It is not advisable to "chase" this bleeding using a transvaginal approach. Only very rarely is the exact bleeding point identified and controlled in this manner.

Transvaginal exploration for bleeding results in ongoing blood loss as the surgeon struggles with relatively poor exposure and visualization. Packing and compression lead to adequate control in most cases, and if not the surgeon should expeditiously complete the procedure, close the incisions, and pack the vagina.[35] Occasionally, in addition to vaginal packing, a Foley catheter inserted through the urethra with the balloon overinflated and then placed on traction adds additional security. Brisk bleeding that does not respond to manual compression for an extended period may suggest a major vessel injury and mandates retropubic exploration or consideration of angioembolization in interventional radiology.

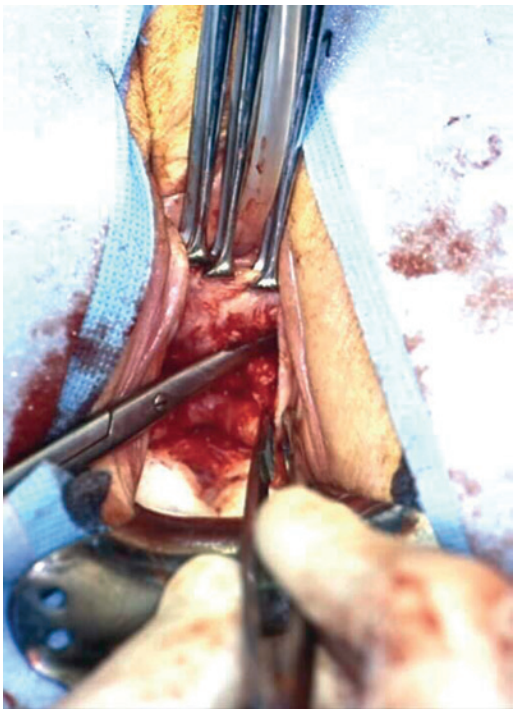


Figure 49.2 The proper plane of dissection. The scissors are directed toward the patient's ipsilateral shoulder. Countertraction is applied to the vaginal wall.

Urinary Tract Injury

During surgical procedures for SUI, the urethra, bladder, or much more rarely the ureters may be injured. The key to the management of each of these injuries is immediate recognition and repair. Long-term sequelae resulting from unrecognized urinary tract injury can be devastating to the patient and can have potentially substantial medico-legal implications for the physician.

Urethral Injury. From the transvaginal side, injury to the urethra may occur during initial dissection of the vaginal wall off the underlying fascia. As noted earlier, excessively deep dissection, especially in reoperative surgical procedures, risks urethral injury. This injury is usually, although not invariably, heralded by an unexpected amount of bleeding. Placement of a urethral catheter before incision will help to identify the urethra intraoperatively and in the case of urethral injury will allow immediate recognition as the catheter becomes visible in the operative field.

If a urethral injury is suspected, urethroscopy may be performed. The urethra should be repaired immediately and closed primarily in two layers by using absorbable sutures in a watertight fashion. The urethra can be repaired over a ≥14Fr catheter. It is not necessary to leave a drain other than the urethral catheter. The integrity of the repair can be tested by injecting saline through a syringe attached to an angiocatheter (intravenous [IV]) sheath into the urethral meatus adjacent to the catheter with the balloon snugged up against the bladder neck. Failure to recognize the injury or failure to repair it properly risks urethrovaginal fistula.

The urethra may also be injured during trocar placement in midurethral sling procedures, needle placement for transvaginal suspensions, or cystocele repair. Countertraction during the initial dissection, maintenance of adequate exposure, and a working knowledge of the anatomy are helpful in avoiding urethral injury.

The incidence of urethral perforation during midurethral sling placement is low, ranging from 0.2% to 2.7%;[8,23,27,32] however, in the event of a concomitant urethral injury during a planned synthetic sling, it is advisable to repair the urethra and abort the sling procedure until the urethra is completely healed.[7] An autologous sling is considered a safer alternative than a synthetic sling in the setting of a urethral injury as a SUI procedure, but there are few if any data supporting this notion.

The urethra is rarely injured during retropubic surgical procedures because the middle and distal thirds are protected by the symphysis pubis.

Bladder Injury. Intraoperative bladder injury may occur during transabdominal and transvaginal SUI surgical procedures. The potential for urinary tract injury varies considerably with the experience of the surgeon,[23,36] as well as with the operative approach. Several studies have reported a bladder perforation rate of 1–8% during passage of needles or trocars for placement of pubovaginal or midurethral slings.[8,22,32,37] Most literature documents a higher risk of bladder injury with the retropubic approach (3–6%) as compared with the transobturator approach (0.4–0.7%) during midurethral sling operations.[23,32,37,38] Repeat surgical procedures are almost certainly associated with a higher risk of urinary tract injury in patients undergoing midurethral sling operations.[23,31]

Injury to the bladder during midurethral sling procedures is diagnosed intraoperatively by careful endoscopic examination of the bladder and bladder neck with a flexible cystoscope including retroflexion and examination of the bladder outlet region, or a rigid cystoscope using a 70-degree lens. Inspection is performed with a completely full bladder following passage of the trocars but before deployment of the midurethral sling. The bladder should be filled and then examined to ensure that a small injury does not go unrecognized in a fold of the bladder wall. To avoid injury during trocar needle passage, the urethra should be clearly palpated, the bladder drained, and the pelvic anatomy well delineated. If a bladder injury is noted intraoperatively, the trocar should be removed and reinserted after draining the bladder. The bladder is then reinspected to assure that the re-passing of the trocars was successful.

Bladder injury from a trocar usually does not require primary closure and when addressed intraoperatively has not been shown to have long-term adverse sequelae.[37] Postoperative Foley catheter drainage of the bladder after trocar cystotomy has not been extensively studied, and there are a paucity of published data evaluating the need for prolonged catheterization. In a retrospective review of 30 patients experiencing trocar cystotomy at the time of suprapubic midurethral sling placement, Crosby et al.[39] found that 80% passed a voiding trial the day of surgery and were discharged home without a catheter. The 20% who failed a voiding trial were sent home with a Foley catheter and successfully voided within 4 days. At 6-week follow-up, no patient experienced voiding dysfunction or irritative bladder symptoms and no patient required additional intervention.

Although not mandatory, prolonged catheterization may be desired in patients with a larger cystotomy to avoid urinoma, fistula formation, and pelvic abscess. Also, catheterization and continuous bladder irrigation may be required if there is significant gross hematuria after cystotomy.

During a transvaginal pubovaginal sling procedure or during performance of urethrolysis, it is common to perforate the endopelvic fascia intentionally to gain entry to the retropubic space. This perforation maneuver is often done sharply with curved scissors. The surgeon must be aware of lower urinary tract anatomy during this maneuver to avoid injury. Countertraction on the pelvic fascia away from the side of interest as the scissor perforates into the retropubic space will help to avoid injury. If injury occurs, lower urinary tract perforation in this setting is often larger than that seen with the passage of the trocars during a midurethral sling. The injury should be isolated and closed in two layers. A suprapubic drain can be placed and the lower urinary tract drained for several days to ensure healing. In addition, ureteral patency should be assessed in this setting because the injury can track proximally on the trigone.

Injury to the bladder during retropubic operations is usually confined to the anterior bladder wall. This complication is usually easily recognized and repaired. Postoperative Foley catheter drainage is mandatory. During a Burch or MMK procedure, a stitch may be inadvertently placed transmurally into the bladder or urethral lumen. Intraoperative cystoscopic examination identifies these injuries and permits removal and replacement of the suture.[40]

Ureteral Injury. Ureteral injury during surgical treatment of UI is uncommon. The reported incidence of ureteral injury for all incontinence procedures is 0.18–4%.[8,32] With the advent of midurethral slings, these injuries are becoming more rare (0.18–1.22%)[32] given the expected location of the sling at the level of the midurethra. However, the ureter may be kinked or obstructed during Burch or MMK procedures or during vaginal prolapse repair. Virtually all these injuries can be identified by intraoperative cystoscopy. The administration of IV vital dyes such as indigo carmine permits obvious visualization of ureteral efflux that confirms ureteral patency. Suspected ureteral injuries are confirmed by retrograde pyeloureterography. Most of these injuries are related to suture placement. When found, ureteral injuries may be treated by removal of the offending suture and placement of a temporary indwelling ureteral stent. Ureteral transection requires ureteroneocystostomy.

Intraoperative Cystoscopy. Cystoscopy is a low-morbidity procedure that requires little additional time, effort, or resources. However, some additional expense is incurred in performing cystoscopy, and the practitioner requires advanced training in endoscopic examination of the lower urinary tract. Nevertheless, careful cystoscopic examination of the lower urinary tract following SUI surgical procedures enables the surgeon to evaluate the patient for almost all lower urinary tract injuries. If IV vital dye is given, ureteral injury can also be excluded by visualizing efflux from the ureters. In the most recent AUA Guideline on Surgical Management of Female Stress Urinary Incontinence,[8] intraoperative cystourethroscopy is a treatment standard in all patients undergoing a sling procedure. The bladder must be examined when it is full, and careful attention should be paid at the 2- and 10-o'clock positions at the bladder neck and just inside the bladder neck because these are the locations of a majority of lower urinary tract injuries during SUI surgical procedures.

Inexperience with cystoscopy leads to a high rate of missed intraoperative perforations.[36] If perforations are recognized intraoperatively, the lower urinary tract can be quickly repaired and drained if necessary. Unrecognized urinary tract injuries can lead to infection, sepsis, fistula, stones, and other complications.[41] Transobturator slings can be associated with injury to the lower urinary tract 0.4–0.7% of the time,[23,37,38,41] and thus intraoperative cystoscopy should be performed in these cases as well.

Bowel Injury. Multiple reports of bowel injury during surgical procedures for SUI have been reported.[42,43] Fortunately this complication is rare. Bowel injury may occur during retropubic dissection for a Burch or MMK procedure, on entry into the retropubic space during an autologous pubovaginal sling or urethrolysis, or during passage of needle passers or trocars during midurethral sling procedures. These injuries can be devastating complications leading to sepsis, abscess, and even death.[29] Unfortunately, most of these injuries are not recognized until the postoperative period, when they lead to considerable morbidity. Initial signs and symptoms heralding a bowel injury may be subtle, including low-grade fever, abdominal pain, and ileus. If bowel injury is suspected, a diagnostic evaluation including plain and upright abdominal radiographs to ascertain the presence of intraabdominal free air and cross-sectional imaging should be pursued expeditiously. Laparotomy, repair of the bowel injury, and, possibly, bowel resection are necessary for definitive treatment. In some cases, temporary proximal bowel diversion may be necessary.

Postoperative Complications

Voiding Dysfunction and Urinary Retention. Bladder outlet obstruction (BOO) may occur following SUI surgical procedures. This complication manifests as prolonged complete urinary retention, persistently elevated post-void residual urine volume, or as variably bothersome and poorly categorized lower urinary tract symptoms including combinations of obstructive symptoms and urinary urgency or UI and recurrent urinary tract infection. These last two groups are difficult to identify and are often not recognized as having BOO by many investigators. The incidence of postoperative voiding problems across various procedures is variable and difficult to compare. A meta-analysis published in 2014 found urinary retention rates <6 weeks postoperatively to be higher in Burch suspension (17%) followed by pubovaginal slings (12%), and that number was reduced to 7.6% and 7.5%, respectively, at >6 weeks, while midurethral slings had a retention rate of 2.3–3.1% in both groups.[32] While the incidence of retention was higher in Burch suspension, the need for intervention was zero. Meanwhile, midurethral slings require intervention for retention or voiding dysfunction in 1–3% of women.[26,27,32] The incidence of voiding dysfunction, including urinary retention (16.6%)[22] and de novo urgency and urge UI following midurethral sling procedures ranges from approximately 2% to 25%.[42–46] In the TOMUS multicenter prospective study, transobturator slings

had fewer "obstructive" complications than did retropubic midurethral slings.[27] This has been verified by additional studies and summarized in the 2015 Cochrane review of midurethral slings.[28] The minimally invasive midurethral sling procedures are mechanistically tension free, and as such it is not surprising that they likely result in an overall lower incidence of postoperative voiding dysfunction than that seen with other types of open SUI procedures.

The finding of absolute prolonged urinary retention makes the diagnosis of obstruction fairly straightforward if the patient had relatively normal voiding dynamics preoperatively. One potential exception is the patient who voids primarily by pelvic floor relaxation. Female patients may void without a perceptible increase in intravesical pressure, and in these individuals, even a modest increase in outlet closure forces, such as that caused by a sling, may result in urinary retention. In many other patients, the diagnosis of BOO is extremely difficult. Urodynamic studies, especially video urodynamic studies, are often pursued diagnostically but may not be helpful in many cases because the classic "high pressure–low flow" pattern may not be present. Nitti and colleagues have suggested that the radiographic finding of a discrete area of narrowing in the urethra in combination with dilation of the proximal urethra is highly suggestive and potentially diagnostic of female BOO.[47] However, in spite of this, no pressure-flow urodynamic criteria accurately predict successful voiding following urethrolysis.

Various nomograms have been developed for the diagnosis of female BOO but none is absolutely accepted as the gold standard. For patients not in frank urinary retention, the diagnosis of BOO is strongly suggested by the postoperative onset of irritative voiding symptoms, recurrent UTIs, and a poor urine stream. Physical examination may be completely normal or suggest an oversuspended midvaginal segment ("swan neck deformity") or the lack of mobility of the urethra following insertion of a metal sound. De novo prolapse should be excluded as a cause of postoperative BOO. An unrecognized and thus unrepaired cystocele may result in BOO following SUI surgical procedures.

Before surgical intervention for postoperative urinary retention is considered, many transient causes should be considered. These are potentially unrelated to iatrogenic BOO and the mechanical effects of the procedure. In the immediate postoperative period, pain is a common reason for delayed micturition. Similarly, postoperative pain relief from narcotic analgesics may suppress micturition as well. These effects are temporary and a period of catheterization for several days postoperatively allows resumption of normal voiding in most cases. Other potential causes of temporary postoperative urinary retention include patient immobility, edema at the operative site, and retropubic hematomas.

Management options for prolonged voiding difficulties include repeated voiding trials, initiation of intermittent urethral catheterization, and incision of the sling or urethrolysis. Some investigators recommend conservative therapy for postoperative voiding dysfunction for ≤3 months before surgical revision is attempted.[48] Most patients resume normal voiding following midurethral slings within 1 to 2 days of the procedure. However, some patients may be delayed for 1 to 2 weeks and those with a history of prior SUI surgical procedures or those undergoing concomitant prolapse repair may be further delayed.[49,50] A prolonged time to intervention for BOO may be associated with long-term, potentially irreversible bladder dysfunction, even following successful urethrolysis.[46,51]

As compared with obstructive symptoms such as hesitancy, straining, and poor force of urine stream, overactive bladder symptoms resulting from iatrogenically induced BOO following an anti-UI surgical procedure are less likely to improve despite a technically successful operation.[52] In one series, voiding symptoms resolved in 82% of obstructed patients following urethrolysis, whereas overactive bladder (storage) symptoms resolved in only 35%.[53] In this series, increased time to intervention did not correlate with persistence of OAB symptoms after urethrolysis.

Once the diagnosis of BOO is considered or established, options include long-term intermittent urethral catheterization, transvaginal or retropubic urethrolysis, or transvaginal incision of the sling. Care must be taken to avoid urethral injury while performing a sling incision because the urethral wall may be draped over the taut sling and may be inadvertently pinched and perforated during dissection and isolation of the sling for incision. Generally, the longer the time from sling surgery to sling incision, the more difficult it can be to find the sling during repeat exploration. Following isolation and division of the sling, the edges of the cut sling often separate by 1–2 cm, a finding indicating a satisfactory result. Iatrogenic obstruction resulting from autologous fascial slings is often treated in this manner as well.[54] However, historically, some investigators waited up to 3 months before consideration of sling incision for obstructing fascial slings (Fig. 49.3).

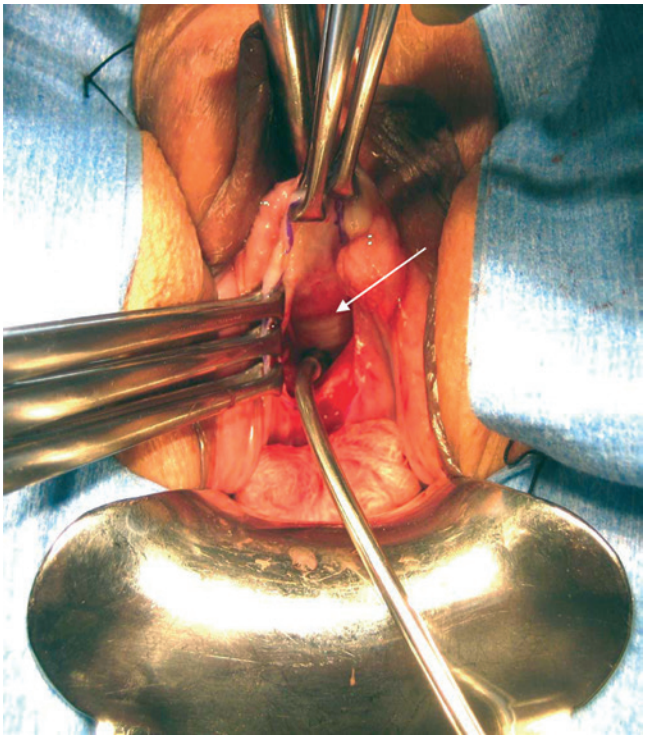


Figure 49.3 Transvaginal incision of a fascial sling. The sling in this case is seen between the tip of the sucker and the white arrow as a shiny band of tissue.

For patients in whom transvaginal incision fails, or in patients who underwent a nonsling procedure as the cause of their BOO, urethrolysis may be performed.[55] Through a transvaginal or retropubic approach,[55–57] the retropubic space is entered and the urethra is sharply dissected off the posterior surface of the symphysis pubis and is freed from the surrounding scar. The limbs of the sling or other retropubic attachments are isolated and divided in the retropubic space. Lateral attachments to the pelvic sidewall are incised as needed for patients who previously underwent a Burch or paravaginal repair. A transvaginal, suprameatal approach to urethrolysis has also been described and may be particularly applicable to those patients who previously underwent an MMK procedure.[57]

Recurrence of SUI symptoms following urethrolysis or sling incision may occur in 9–28% of patients.[46,58,59] Patients should be counseled regarding this possibility preoperatively because some may wish to continue performing intermittent catheterization rather than risk recurrent SUI.

Vaginal Exposure and Urinary Tract Erosion. *Vaginal exposure* refers to the finding of exposed sling material in the vaginal canal postoperatively, whereas *erosion* implies the finding of material within the lumen of the urinary tract at some time interval postoperatively that was clearly documented as not being within the urinary tract intraoperatively. The incidence of these complications in midurethral slings ranges from 2.5% to 4.7%.[8,29,32,60]

Exposure of material in the genital tract may be related to surgical technique, infection, or the physical properties of the implanted material. The exposed material may be located in the midline at the prior vaginal incision line or at the anterolateral vaginal wall at the fornix, or anywhere in between. Midline exposures imply wound dehiscence. Lateral exposures may result from an unrecognized vaginal wall perforation or injury at the time of sling placement.

Patients are usually symptomatic and have complaints suggesting an exposure, including a malodorous vaginal discharge, vaginal spotting, vaginal pain, and dyspareunia. Patients may present several days to months postoperatively. On physical examination, the exposed material is often visible, but physical findings may also be quite subtle (Fig. 49.4).[61] Granulation tissue suggests the presence of an exposure. Exposed synthetic mesh is often palpable within the vagina, although the patient's discomfort may preclude a complete examination.

Factors responsible for exposure include the physical nature of the implanted material, the quality of the vaginal tissues of the host, sling tension, wound healing, and infection.[62] It appears that multifilament materials are at greater risk for exposure than monofilaments.[63] In keeping with this, in the United States only monofilament transvaginal mesh products are currently available. In addition, a pore size that is large enough to permit fibroblast and macrophage infiltration and subsequent tissue ingrowth (generally considered to be >75 microns) is an important factor in preventing exposure.[64] Synthetic material other than polypropylene slings, such as Stamey bladder neck suspension bolsters, placed years earlier for the treatment of SUI may eventually become infected and create a draining sinus or may become a nidus of pelvic infection or recurrent UTIs.[65] These materials will require exploration and explantation.

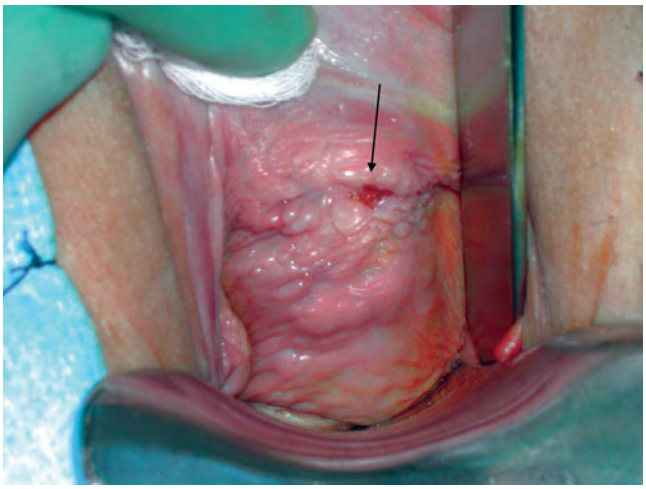


Figure 49.4 A small area of beefy granulation tissue (black arrow) is seen along the anterior vaginal wall in this patient, a finding suggesting vaginal extrusion.

In the absence of significant symptoms such as pain, small genital sling exposures may heal with conservative management including the application of topical estrogen creams for up to 6 weeks.[66] Larger exposures can be managed with copious irrigation and secondary closure in the operating room by widely mobilizing and rotating vaginal wall flaps with coverage of the exposed material. Some patients with large exposures, or with significant pain or dyspareunia, may benefit from excision and removal of a variable amount of the exposed segment of the sling and rotational vaginal wall flap closure of the defect.

In the immediate postoperative period, avoiding vaginal intercourse or vaginal tampon use should be strongly encouraged for the first 4 to 6 weeks following vaginal surgery to avoid disruption of the vaginal incision and subsequent exposure of the sling material.

Urinary tract erosion may occur with synthetic, biologic, or autologous materials.[67] This is a devastating complication that, unlike vaginal exposure, is almost always managed operatively. Whether urinary tract erosion results from a missed intraoperative urinary perforation or from migration of the material into the urinary tract sometime following the surgical procedure is unclear. Patients may complain of irritative lower urinary tract symptoms, recurrent UTIs, hematuria, dysuria, and pelvic pain. The definitive diagnosis is usually made endoscopically (Figs. 49.5 and 49.6A, B).

For intravesical erosions, endoscopic scissor or laser transection of the intravesical portion of the eroded sling may permit the remaining sling material to retract outside the urinary tract.[68–72] However, an endoscopic approach risks ongoing pain as well as recurrent erosion of the synthetic material into the urinary tract. If this procedure fails or is technically not feasible, then open[73] or laparoscopic[74] exploration with removal of the eroded material, closure of the urinary tract, and postoperative drainage will be necessary. Explantation of an eroded mesh sling in the urethra can usually be done completely through a transvaginal approach.[75]

Neuromuscular Injury. Several nerves traverse the deep pelvis as well as superficially within the lower abdominal soft tissues. These nerves are at risk for injury during SUI surgical procedures in female patients. Stretch or compression injury to the femoral nerve can result from positioning. This complication results in sensory changes to the anterior thigh or, in more severe cases, weakness of hip flexion. Severe abduction and external rotation of the thigh should be minimized during positioning to avoid this complication.

The peroneal nerve can be injured by direct compression while the patient is in the lithotomy position. Lateral direct pressure on the peroneal nerve between the stirrup at the lateral aspect of the knee joint and the fibular head for a prolonged period may result in peroneal nerve palsy and foot drop.[76] This injury may also occur with compression of the fibular head against the stirrup holder, especially when candy cane stirrups are used, because the leg rotates externally after placement in the holders. The ilioinguinal and iliohypogastric nerves may be injured by suprapubic trocar placement or dissection resulting in pain in the suprapubic region.[77]

Groin pain or neurologic symptoms following midurethral sling are more likely to occur after the transobturator approach compared to the retropubic approach.[27,28,78] The incidence ranges from 6.4% to 17% in most series,[28,79–81] and a majority will have resolution within a few weeks.[82,83] The pain may occur secondary to adductor muscle injury or nerve injury, and therefore such an approach may be less desirable in an active person or athlete. In addition to avoiding technical errors during sling placement, positioning the patient's legs with increased hip flexion provides a greater distance between the trocar and obturator neurovascular structures.[84,85]

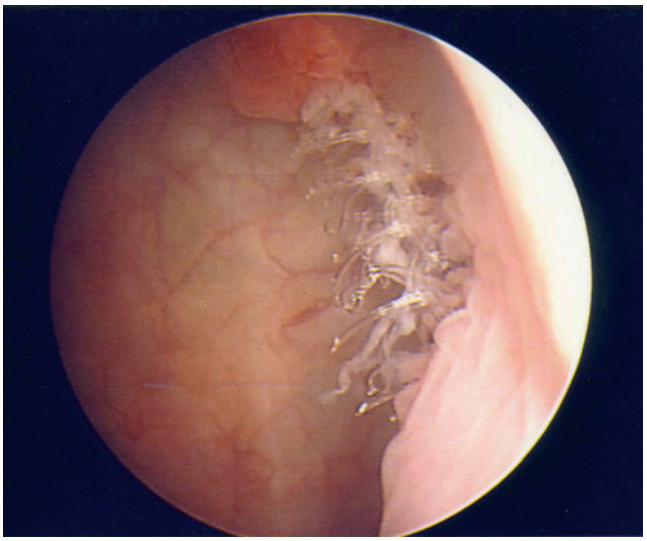


Figure 49.5 Intravesical erosion of a polypropylene sling.

Pain. Some patients present months to years following midurethral sling with vaginal and/or pelvic pain without evidence of mesh exposure or erosion. All patients with pain potentially related to sling placement or SUI surgery should be treated with conservative measures initially. These may include nonsteroidal antiinflammatories, physical therapy, pelvic floor massage, and vaginal estrogen creams either individually or in combination. A careful physical exam must be performed specifically to evaluate for vaginal "bands" and reproducible pain upon palpation of these "bands" or trocar sites in the suprapubic area or inner thigh. Pain elucidated on exam, especially if associated with a vaginal band, often, though not invariably, responds favorably to excision. At the time of excision it is often found that the sling is on excessive tension or there is excessive scarring and fibrosis. It is not recommended to remove asymptomatic mesh without associated complications as side effects related to nearby tissue damage and/or recurrence of SUI may occur.[86]

Patients with generalized pelvic pain following sling placement that is not reproducible on examination and has not responded to conservative measures may or may not respond to excision of the synthetic material. In such cases, the choice to proceed with surgery should be made with extreme caution in extraordinary cases and only when there is a temporal relationship between placement of the sling and the onset of the pain. Generalized pain is often difficult to treat and may or may not respond to sling excision, and patients should be thoroughly counseled regarding this potential outcome.

In all cases of surgical excision of the sling due to pain, it is controversial whether the entire sling has to be removed. Removing the entire retropubic or transobturator portions of the sling is a large surgical undertaking with potentially

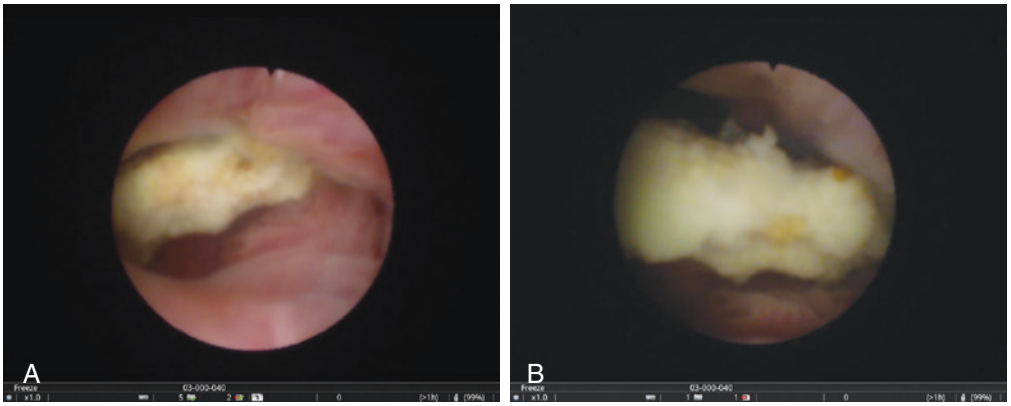


Figure 49.6 A, Calcification on urethral erosion of a midurethral sling. B, Calcification on the bladder neck erosion of a midurethral sling.

significant morbidity. Whether this extensive procedure is necessary in all cases is not well defined. Alternatively, only removing the transvaginal portion of the sling may adequately treat many patients' pain. Typically, when the pain can be localized on physical examination, we prefer to remove only the portion to which the pain has been localized. When applicable this includes the sling material up to the level of the inferior pubic ramus bilaterally and results in improvement of pain in up to 80% of individuals.[87] This can be done as a day surgical procedure and avoids potential major complications associated with removal of the pelvic portion of the sling such as neuromuscular injury, major vascular injury and bleeding, and injury to the urinary tract. As discussed earlier, the transobturator midurethral sling is more likely to be associated with groin pain or neurologic symptoms compared to retropubic midurethral slings.[27,28,88] Patients with recalcitrant pain often require removal of the arm of the transobturator sling, which can be technically challenging. Innovative approaches have been described for removing residual sling in these difficult cases.[83]

Sexual Dysfunction. Historically the effect of stress urinary incontinence surgery on sexual function has been controversial and inconsistently reported. Some investigators have found that female sexual function and coital incontinence improves following surgical treatment of SUI,[89–92] while others have reported deterioration,[93] and yet others reported no change in sexual function.[94–98] The risk of postoperative sexual dysfunction or dyspareunia following SUI surgery is low,[28,93] but any such complaint should be assessed by a thorough physical examination as it may be related to vaginal scarring, banding or narrowing, or mesh sling exposure.[99]

Dyspareunia is only one form of sexual dysfunction, but it may occur following anti-UI surgical procedures. Vaginal anatomy is altered by the surgical treatment of SUI. The vaginal axis can be shifted, thus changing the angulation of the vaginal canal. Circumferential narrowing of the vagina may result from excessive trimming of vaginal wall during prolapse repair or simply as a result of aberrant scarring. Dissection along the anterior vaginal wall may cause nerve injury and neuroma formation. Other ill-defined and poorly understood factors contributing to postoperative sexual dysfunction may exist.

Other Postoperative Complications. Urinary fistula following SUI surgical procedures is quite rare. Nevertheless, an unrecognized and unrepaired intraoperative injury to the ureter, bladder, or urethra may result in ureterovaginal, vesicovaginal, or urethrovaginal fistula, respectively. Intraoperative recognition of the injury is critical to prevent fistula formation, and thus the importance of a careful intraoperative endoscopic examination and confirmation of urinary tract patency cannot be overemphasized.

De novo vaginal prolapse including cystocele and enterocele may also occur following anti-UI surgical procedures. Alteration of the vaginal axis especially with open retropubic procedures such as the Burch or MMK may result in anatomic changes that predispose patients to postoperative vaginal prolapse. Predicting which patients will develop postoperative vaginal prolapse is exceedingly difficult.

Urethral Bulking Agents

In general, the morbidity associated with peri- or transurethral injectable bulking agents is low. UTI, short-term voiding dysfunction[100] including urinary retention, and hematuria are seen with all the urethral injectable agents. Transient dysuria and short-term elevated post-void residual urine are not uncommon following urethral bulking injections. For those individuals with persistent symptoms, UTI should be excluded. Calcium hydroxyapatite (Coaptite, Boston Scientific) is associated with the same complications mentioned above. In addition, one study reported serious adverse events in two patients related to Coaptite injection. These included vaginal erosion and tracking of the injectable agent under the trigone.[101] Urethral prolapse after Coaptite injection has also been reported in two patients with resolution after local excision.[102,103] Along with the more commonly reported adverse events, silicone particles (Macroplastique, Uroplasty Inc) have a reported transient urinary retention rate of 6–10%,[104,105] and carbon beads (Durasphere, Boston Scientific) have been associated with local lymphatic and periurethral migration, periurethral abscess, and urethral prolapse in a few cases.[106–108] Distal and systemic migration of urethral injectable agents including Teflon and carbon-coated beads has been reported. The long-term ramifications of these synthetic materials in the lymph nodes, lungs, and other organs are unknown.[109]

COMPLICATIONS RELATED TO URGE INCONTINENCE SURGERY

Botulinum Toxin A

Although BT is potentially quite toxic, few complications have been reported with its use. Local and self-limited complications such as hematuria, dysuria, pain, and infection occur at acceptable rates; however, the most worrisome potential complication, respiratory suppression, has not been reported with urinary tract injection of BT. Urinary retention and elevated post-void residual following intradetrusor injection in nonneurogenic detrusor overactivity has been reported in 5–16% and 35–60% of patients, respectively.[110,111] Because the pharmacologic effects of BT are not manifest for 3 to 14 days following injection, immediate urinary retention following BT injection is likely related not to the agent itself but rather to other factors including instrumentation. Urinary retention or voiding dysfunction resulting from BT usually occurs 1 to 2 weeks following injection. Kuo and colleagues[110] reported that risk factors for acute urinary retention include male gender, age greater than 75 years, and baseline PVR greater than 100 mL. There is a limited amount of literature in regard to urinary retention risk with injection of Botox at the bladder base or trigone; however, what is available has not shown an increased risk.[110,112,113]

Scattered reports of systemic adverse effects have been noted with the use of the Dysport formulation of BT, which is currently not available in the United States. These reactions have included generalized muscle weakness and hyposthenia in ≤6% of individuals and appear to be dose related because they have not been reported with the use of lower doses of the material.[114] Botox is currently the only BT for-

Table 49.3 Adverse Events Related to Sacral Neuromodulation (InterStim Implantation) in 202 Patients

Adverse Event	Percentage (%)
Malfunction secondary to trauma	8.9
Lead migration	5.9
Lack of efficacy	3.5
Infection	3.5
Pain at stimulator site	2.9
Hematoma requiring re-exploration	1.5

(Adapted from White WW, Mobley JD, Doggweiler R, et al. Incidence and predictors of complications with sacral neuromodulation. Urology. 2009;73:731-35.)

mulation that is FDA approved for urologic indications in the United States. One case of mild arm weakness has been reported with the use of the Botox formulation in the United States; however, this was after use in a nonurologic application.

Sacral Neuromodulation

Several complications related to sacral neuromodulation have been well documented. Overall, the reported surgical revision or removal rate has been reported to be ≤16% to 32%.[115–117] White and colleagues[118] reported adverse events in 202 patients (Table 49.3); in these patients, device malfunction secondary to trauma and lead migration were the most common. Pain at the stimulator site is the most frequently reported complication in many series.[116,117,119,120] Physical examination may reveal a fluid collection around the device requiring drainage or infection requiring explantation of the IPG and lead. In the setting of pain at the IPG site that is reproducible on palpation of the device, and which does not respond to conservative measures, the patient should be treated with surgical relocation of the IPG. Generally, relocation of the device into a superior or inferior position on the buttock or lower abdominal site improves the pain. For those with pain at the IPG site that is not reproduced on palpation, the device should be turned off for a period of time and the patient reexamined. If the pain resolves, then further investigation should commence. Although not considered a complication, patients should be well informed of the inability to obtain a lumbar, sacral, or pelvic MRI with the implanted device. If MRI of these areas is imperative the device should be explanted with the option of reimplantation after the MRI if the patient so desires.

Conclusions

Surgical treatment of urinary incontinence has changed significantly over the last 20 years. With the development and popularity of the midurethral polypropylene sling the types of complications seen in the surgical treatment of SUI have also changed. Thankfully, these complications are uncommon and in the current environment surrounding the use of transvaginal mesh, the FDA has reiterated that the standard polypropylene mesh midurethral sling is safe and effective in the treatment of SUI.[15] It is imperative to select the proper patient for the appropriate anti-UI operation, as the optimal situation is to prevent or minimize the risk of adverse outcomes. We hope this chapter will be a valuable resource in your practice should the complications reviewed above arise.

References

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Chapter 49 Questions

1. A 52-year-old woman is undergoing a retropubic midurethral sling procedure. Cystoscopy after placement of the trocars reveals a bladder perforation. What is the most likely location in which the trocar will be seen?
   a. Bladder dome
   b. Bladder trigone
   c. 2- or 10-o'clock location of the anterior bladder wall
   d. 5- or 7-o'clock location of bladder neck
   e. Urethra

2. A patient returns to the office 2 years after a midurethral sling with complaints of mixed urinary incontinence, weak urinary stream, and sensation of incomplete bladder emptying. Physical exam reveals an oversuspended anterior vaginal wall with little mobility on Valsalva. Catheterized post-void residual is 200 mL. Serum creatinine is in the normal range, and urinalysis and urine culture are negative. What is the next step in definitive management?
   a. Retropubic urethrolysis
   b. Transvaginal sling incision
   c. Place suprapubic tube
   d. Alpha-blocker therapy
   e. Antimuscarinic therapy

3. During the dissection for placement of a retropubic midurethral sling in a healthy 52-year-old female, it is noticed that there is a very small urethral injury. Prior to surgery the patient was very adamant that she must have her stress incontinence fixed now as work and family obligations make this the only time she can have surgery and adequate recovery time. What is the next step after repairing the urethral injury?
   a. Proceed with retropubic midurethral sling placement
   b. Place a transobturator midurethral sling
   c. Placement of an autologous fascial pubovaginal sling
   d. Cystoscopic injection of Coaptite
   e. Intradetrusor injection of Botox

4. What is the most common complication of Botox injection?
   a. Guillain-Barre syndrome
   b. Sepsis
   c. Striated muscle weakness
   d. Respiratory suppression
   e. Elevated post-void residual

5. A healthy female patient had a sacral neuromodulation lead and implantable pulse generator (IPG) placed 6 months ago for refractory overactive bladder. She now complains of pain over the IPG site. Physical exam is unremarkable. What is the next step in management?
   a. Explant the device
   b. Relocate the device into a new pocket either superiorly or inferiorly in relation to the old pocket
   c. Broad-spectrum antibiotics for 21 days
   d. Interrogate the device and turn device off to see if the pain resolves
   e. Replace IPG

6. A 78-year-old female returns 4 days following injection of a urethral bulking agent with complaints of urinary urgency and frequency. What is the next step in management?
   a. Place a Foley catheter
   b. Trial of antimuscarinic medication
   c. Treatment with 7 days of Augmentin
   d. Urinalysis and urine culture
   e. Repeat cystourethroscopy

7. A healthy female undergoes surgical treatment of pelvic organ prolapse and stress urinary incontinence. One hour following sacrospinous ligament fixation and transobturator sling she complains of right sided foot drop. The most likely cause is injury to which of the following nerves?
   a. Sciatic nerve
   b. Femoral nerve
   c. Obturator nerve
   d. Peroneal nerve
   e. Ilioinguinal nerve

8. The retropubic space is entered transvaginally during placement of a pubovaginal sling, and brisk bleeding is encountered. What is the next step in management?
   a. Place vaginal packing and manually compress the anterior vaginal wall
   b. Transvaginal exploration of the retropubic space
   c. Transabdominal exploration of the retropubic space
   d. Abort the procedure and transfer the patient to interventional radiology for angiography and possible angioembolization
   e. Retroperitoneal exploration and ligation of the ipsilateral iliac vessels

9. Three months following a transobturator midurethral sling placement a 58-year-old female complains of dyspareunia, urgency, frequency, and recurrent urinary tract infections. On vaginal examination a 1-cm area of exposed mesh is identified. There are no areas of vaginal or pelvic tenderness. Her catheterized post-void residual is 200 mL. What is the next step?
   a. Vaginal estrogen cream
   b. Alpha-blocker
   c. Both vaginal estrogen and alpha-blocker
   d. Transvaginal sling incision and removal of exposed portion of the mesh sling
   e. Transvaginal and transperineal exploration and removal of the entire mesh sling

10. During a retropubic midurethral sling the trocar is seen intravesically on endoscopic examination. The next step is:
    a. Remove the trocar and abort the procedure
    b. Remove the trocar, abort the procedure, and repair the bladder in two layers with absorbable synthetic suture

c. Abort the procedure and place an autologous fascia pubovaginal sling
d. Remove and reinsert the trocar in an extravesical location and proceed with placement of retropubic midurethral sling
e. Remove the trocar and change to placement of a transobturator midurethral sling

Case Studies

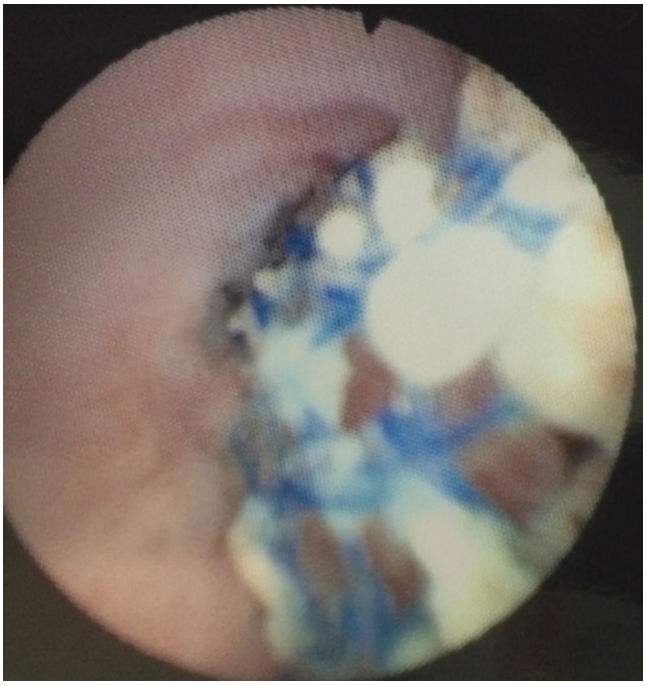
CASE 1

A 30-year-old healthy female presents with complaints of recurrent urinary tract infections (UTIs) for the last 2.5 years. Her past medical and surgical histories are remarkable only for a retropubic midurethral sling placed 3 years ago. She has failed multiple courses of antibiotic therapy. Her physical exam reveals slight tenderness to palpation of the anterior vaginal wall overlying the urethra, but is otherwise unremarkable. Her post-void residual by bladder scan is 20 mL. Urinalysis and culture are consistent with UTI, and she is started on appropriate antibiotic therapy.

1. What is the next step in management?
   a. Start on intermittent self-catheterization
   b. Cystourethroscopy
   c. Postcoital antibiotic prophylaxis
   d. Vaginal estrogen cream
   e. Prophylactic nightly antibiotic for 3 months

2. On cystourethroscopy the finding presented in Case Fig. 49.1 is noted. What is the next step required for treatment?
   a. Endoscopic removal of foreign body
   b. Retropubic exploration, removal of entire mesh sling, and urethral repair
   c. Transvaginal exploration, intraurethral mesh excision, and urethral repair
   d. Transvaginal mesh excision, urethral repair, and placement of a new midurethral sling
   e. Placement of suprapubic tube

3. Six months after mesh excision and urethral repair she returns complaining of recurrent stress urinary incontinence (SUI). Her UTIs have not returned, she continues to void to completion, and she has no other urologic complaints. What options are available to her for treatment of her recurrent SUI?
   a. Autologous pubovaginal sling
   b. Transobturator midurethral sling
   c. Retropubic midurethral sling
   d. Injection of urethral bulking agent
   e. All of the above

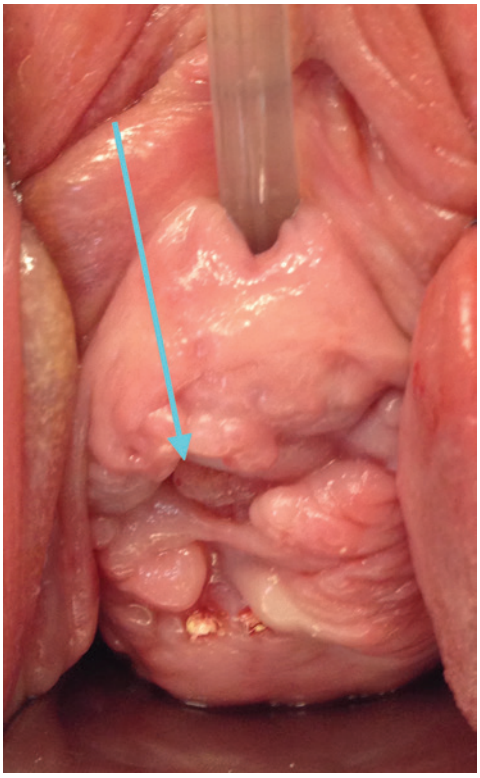


Case Figure 49.1

CASE 2

A 57-year-old sexually active woman is referred for dyspareunia and bothersome recurrent SUI 5 years after a transobturator midurethral sling. She has no voiding complaints. Vaginal exam reveals the finding shown in Case Fig. 49.2. On physical exam she demonstrates SUI in the supine position and empties her bladder adequately with a post-void residual of 25 mL.

1. What is the next step in management?
   a. Topical estrogen cream for 6 weeks
   b. Six-week course of empiric antibiotics in addition to topical estrogen cream



Case Figure 49.2

c. Excision of exposed mesh in the office using local anesthesia
d. Transvaginal excision of exposed mesh, placement of autologous fascial sling, creation of vaginal wall flaps, and closure of vaginal epithelium
e. Transvaginal excision of exposed mesh and placement of biologic dermal graft to close vaginal defect

2. Six months after mesh excision and placement of an autologous fascial sling she complains of urinary frequency and urgency that were not present preoperatively. Vaginal exam is unremarkable, her incision is well healed, there is no evidence of urethral oversuspension, and there is no tenderness to palpation of the anterior vaginal wall. Her Qmax on noninvasive uroflow is 12 mL/s and her post-void residual is 175 mL. What is the next step in definitive management?
   a. Placement of sacral neuromodulation test lead
   b. Placement of suprapubic tube
   c. Video urodynamics
   d. Trial of antimuscarinics
   e. Endoscopic intradetrusor injection of Botox

3. The video urodynamics reveal low-pressure involuntary bladder contractions, a maximum cystometric capacity of 425 mL, and normal compliance. SUI was not demonstrated. She voided with a sustained detrusor pressure in excess of 40 cm H_2O with a flattened urinary flow pattern and Qmax of 11 mL/s. Voiding images were remarkable for nonopacification of the urethra. Post-void residual was 150 mL. What is the next step in management?
   a. Transvaginal sling incision
   b. Suprapubic exploration and incision of the sling sutures below the level of the rectus fascia
   c. Placement of suprapubic tube
   d. Retropubic exploration and sling removal
   e. Prescribe VESIcare 5 mg by mouth daily

Answers

1. **c.** Bladder injury is a common occurrence during trocar passage in the performance of a midurethral sling. The most common location where the trocar injury will be seen is the anterior bladder wall, usually in the 2- or 10-o'clock position. It is important to inspect the bladder while full and use a flexible cystoscope or rigid 70-degree cystoscope.
2. **b.** Retropubic urethrolysis is more invasive, and suprapubic tube placement would not be a definitive treatment of this patient. Alpha-blocker therapy will not improve the likely anatomic obstruction. Antimuscarinic therapy may offer some symptomatic relief; however, this will not treat the underlying problem.
3. **c.** Placement of mesh after urethral injury is contraindicated. Given this patient's young age Coaptite would have inferior long-term efficacy compared to midurethral and fascial slings and would require repeat injections. Botox is indicated for the treatment of overactive bladder and urinary urge incontinence.
4. **e.** Guillain-Barre syndrome has never been reported after intradetrusor botulinum injection for lower urinary tract dysfunction. While urinary tract infections are not uncommon following intradetrusor botulinum injections, sepsis has not been reported. Generalized muscle weakness has been reported with Dysport; however, this formulation is currently not available in the United States. Respiratory suppression has not been reported with use of botulinum toxin in the urinary tract.
5. **d.** Explantation or replacement of the IPG or relocation of the IPG would be premature at this point. Antibiotics are not indicated as there are no signs of infection. Treatment for an infected device would be removal of the device.
6. **d.** Indwelling Foley catheter would potentially mold the recently placed bulking agent leading to inferior results. Transient urgency, frequency, and dysuria are not uncommon following injection of a urethral bulking agent; however, a urinary tract infection should be excluded prior to treatment with an antimuscarinic or empiric antibiotic therapy.
7. **d.** While the sciatic and obturator nerves can be injured during the aforementioned procedures, these injuries will result in buttock pain and inability to adduct the thigh, respectively. Injury to the femoral nerve would result in sensory defect in the anterior thigh and inability to extend the knee. The ilioinguinal nerve provides sensory innervation to the mons pubis and labia majora. The peroneal nerve may be injured with patients in lithotomy position from compression of the nerve at the level of the fibular head.
8. **a.** Most retropubic bleeding encountered during transvaginal surgery will resolve with vaginal packing and compression. For persistent brisk bleeding after an adequate time of compression, retropubic exploration or angiography may be necessary to identify and control bleeding.
9. **d.** Small areas of exposed vaginal mesh may resolve with application of vaginal estrogen; however, larger exposures will require more invasive intervention for treatment. The elevated post-void residual and urgency frequency suggest that there is also a component of bladder outlet obstruction and this will not be treated by estrogen therapy alone. Alpha-blockers will not treat the iatrogenically created bladder outlet obstruction. The patient does not complain of groin or perineal pain, and therefore removal of the entire sling is not indicated.
10. **d.** Recognition of trocar entry into the bladder during midurethral sling is treated by removal and reinsertion of the trocar outside of the bladder. These injuries typically heal without need for formal bladder repair or prolonged catheter drainage. Transobturator trocar passage has a lower risks of bladder perforation; however, the risk still remains, and therefore intraoperative cystoscopy should also be performed in these cases as well. Urethral injury during mesh sling placement requires repair of the urethra and aborting the midurethral sling procedure.

CASE 1

1. **b.** Her post-void residual is minimal, and therefore self-catheterization is unnecessary. Estrogen replacement

would not be indicated in this young, otherwise healthy female without vaginal atrophy. Postcoital antibiotics eventually may be warranted; however, she needs further evaluation of her urinary tract to identify the source of the recurrent infections, which chronologically may be related to her sling placement. Prophylactic antibiotics would not be appropriate before full evaluation is complete.

2. **c.** Endoscopic removal of mesh may be possible for intravesical erosions; however, urethral mesh erosion requires open surgical excision of the eroded mesh. Retropubic exploration and removal of the entire mesh is not required, and placement of another synthetic sling is contraindicated. The patient is emptying her bladder adequately; therefore suprapubic tube is not required.
3. **e.** She has had adequate time to heal after excision of eroded urethral mesh; therefore any of the above options are available to her for treatment of the recurrent SUI. Some patients refuse replacement of mesh products after prior complications; therefore autologous sling and urethral bulking agents are alternative options. Given the patient's young age she should be counseled that urethral bulking agents do not have long-term durability and efficacy. Therefore repeat injections may be required to maintain desired effect.

CASE 2

1. **d.** This woman has SUI and a mesh exposure vaginally. Small defects can be managed conservatively with topical estrogen cream or local excision of the exposed mesh in the office; however, larger defects, such as in the image shown, require secondary closure or excision in the operating room. Furthermore, her SUI is unlikely to be adequately treated with estrogens alone. Antibiotics have not been shown to promote healing of vaginal mesh erosion. Given her recurrence of SUI a fascial sling can be placed during the same operative procedure.
2. **c.** Despite the lack of physical exam findings, there is concern for bladder outlet obstruction following sling in this symptomatic female with elevated post-void residual. Sacral neuromodulation can be used to treat refractory overactive bladder and nonobstructive urinary retention; however, neuromodulation, antimuscarinics, or Botox injections will not treat bladder outlet obstruction if present. A suprapubic tube will indeed drain the bladder; however, it will not aid in definitive treatment of what is likely bladder outlet obstruction from the pubovaginal sling. Antimuscarinics may exacerbate the elevated post-void residual.
3. **a.** Placement of a suprapubic tube will not provide definitive treatment of this patient's bladder outlet obstruction. Suprapubic incision of the sling sutures will not "release the sling." Transvaginal sling incision is required to relieve the obstruction. Retropubic exploration is unnecessarily invasive for sling incision. Overactive bladder symptoms may persist after sling incision, at which point a trial of antimuscarinics would be appropriate.

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50 Complications of Surgery for Male Incontinence

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CHAPTER OUTLINE

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Preoperative Considerations
Procedures for Male Incontinence
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- Device Injury

Male Sling
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- Urethral Injury

Early Postoperative Complications
Artificial Urinary Sphincter
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- Pain and Paresthesia
- Infection

Inflatable Balloon Compression
Delayed and Long-term Complications
Artificial Urinary Sphincter
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- Recurrent Incontinence
- Urinary Retention

Male Sling
- Infection and Erosion
- De Novo Urgency
- Obstruction
- Prolonged Pain and Paresthesia
- Osseus Complications
- Recurrent Incontinence

Conclusions
Chapter 50 Questions and Answers

KEY POINTS

1. Most intraoperative complications are inconsequential if recognized and treated at the time of surgery. On the other hand, urethral injury typically requires aborting the procedure.
2. To facilitate detection of an unrecognized urethral injury, saline or dilute indigo carmine can be instilled alongside the Foley or through the Foley catheter while moving it in a retrograde fashion.
3. Artificial urinary sphincter (AUS) tubing should be handled with rubber-shod clamps, and care should be taken not to injure the device with sharp instruments or needles. Damage to the device can result in leakage of fluid from the device and mechanical failure.
4. Early infection of the AUS, and most likely the male sling, is typically the result of bacterial contamination at the time of implantation.
5. Erosion of an AUS is commonly caused by prolonged catheterization, catheterization without cuff deactivation, or repeated endoscopic manipulation of the urethra. Patients with prior AUS placement or radiation are at an increased risk.
6. Urinary retention that presents as a late complication following AUS or male sling requires endoscopic evaluation for infection or erosion, and to evaluate the urethra and bladder neck for stricture or contracture.
7. De novo urgency following male sling should be evaluated to rule out obstruction or recurrent stress incontinence.
8. Iatrogenic obstruction following placement of a male sling is rare, but not impossible.
9. Patients with an infected male sling may present with chronic low-grade symptoms, such as mild perineal pain or swelling or an intermittently draining sinus tract.
10. The AUS is a mechanical device that inherently carries a risk of mechanical malfunction as well as the need for device revision or replacement.

Introduction

Stress urinary incontinence (SUI) is a potential complication following surgical treatment of benign prostatic hyperplasia (BPH) or prostate cancer or following pelvic radiation. For the men affected, SUI has a significant impact on quality of life.[1,2] The majority of incontinence following radical prostatectomy and some of the incontinence caused by BPH or radiation treatments is the result of sphincteric insufficiency.[3,4]

The artificial urinary sphincter (AUS) is the current gold-standard treatment for male SUI and was first developed in 1983. Male slings were developed in the 1990s as an alternative to the AUS that did not require mechanical manipulation and surpassed the AUS as the most common SUI procedure in 2010.[5] Inflatable balloon compression devices are the final procedural option for male urinary incontinence and have been available since 2002 outside the United States.

In this chapter, we discuss preoperative evaluation of the patient that can influence potential complications. We then briefly describe the surgical procedures most commonly performed for male urinary incontinence, providing context for the reader to appreciate when and why certain complications occur, and, finally, we discuss the potential complications encountered during the procedures with respect to their temporal occurrence (Table 50.1).

Preoperative Considerations

Traditionally most urologists have agreed that patients should be followed for approximately 12 months before pursuing surgical management of postprostatectomy incontinence. However, patients' early recovery of continence and comorbidities predict their likelihood of eventually achieving continence with the incremental improvements that occur during the first year following surgery.[6,7] More recently, earlier intervention, e.g., at 6 months, has been recommended in severe cases where no temporal improvement is seen.[8,9]

The evaluation of a patient with postprostatectomy incontinence should include a thorough history and physical exam. Important aspects of the history include precipitating factors and associated symptoms (frequency, urgency, nocturia, weak stream). The severity of incontinence based on typical pad use and the resultant impact on quality of life are critical to the assessment, especially as these subjective responses directly correlate with 24-hour pad test data.[10] History should address the patient's voiding symptoms prior to prostate surgery as well as history of neurologic disease or symptoms, radiation therapy, additional surgeries/procedures, and prior attempts at treating the incontinence. During the physical exam the patient should be instructed to cough or Valsalva with a moderately full bladder in order to demonstrate the presence of SUI. A focused neurologic exam should be performed.[9]

When the severity of incontinence is in question we perform a 24-hour pad test for objective assessment as well as to help guide our discussion with the patient regarding surgical options and outcome expectations. In a study by Fisher et al., the only preoperative factor predictive of success following a male perineal sling was having a 24-hour pad weight less than 423 grams. Patients with high-grade incontinence and those with very low-grade incontinence have inferior results with a male sling.[11] The reason for the very low-grade incontinence patients being less satisfied was thought to be due to very high expectations in that group.

Urodynamic testing is optional in the evaluation of postprostatectomy incontinence and is thought to be most useful in cases where SUI is not demonstrated, when there is significant bladder overactivity, or in cases of radiation where impaired bladder compliance is suspected. Urodynamic testing allows for determination of the etiology and guides the treatment of male urinary incontinence.[12] The main goals of the urodynamic evaluation are to determine the presence of sphincteric insufficiency and/or bladder dysfunction, to evaluate for obstruction, and to assess detrusor contractility. It is crucial that the study reproduce the patient's symptoms, which in this case would be incontinence. When urodynamics are performed we follow the protocol described by Huckabay et al., which includes evaluation both with and without a urethral catheter.[13] This urodynamic protocol addresses the subset of men with postprostatectomy SUI that do not leak with the catheter in place[4] and allows for documentation of sphincteric insufficiency in these men. In addition, a flow rate without the catheter allows corroboration of free Qmax and Qmax in those patients that have suspected obstruction based on pressure-flow analysis. Some recommend documenting the degree of posterior urethral mobility to determine whether the patient would benefit from retroluminal support with a male sling.[14]

Table 50.1 Complications of Male Incontinence Surgery

	Intraoperative	Early	Late
AUS	Corporal injury Urethral injury Device injury Bleeding	Hematoma Retention Infection Erosion	Infection Erosion Urethral atrophy Mechanical Retention
Male Sling	Bleeding Urethral injury Obturator nerve injury	Hematoma Retention Infection Pain Paresthesia	Infection Erosion De novo urgency Obstruction Prolonged pain Prolonged paresthesia

Procedures for Male Incontinence

ARTIFICIAL URINARY SPHINCTER

Since the introduction of the American Medical System (AMS) 800 in 1983, there have been incremental improvements to the design of the AMS 800 with antibiotic coating introduced in 2008 and 3.5-cm cuff sizing in 2010. Various techniques exist for implantation of the AUS (AMS 800, Boston Scientific Corporation, Marlborough, MA; Fig. 50.1). A perineal and a lower abdominal incision (either transverse

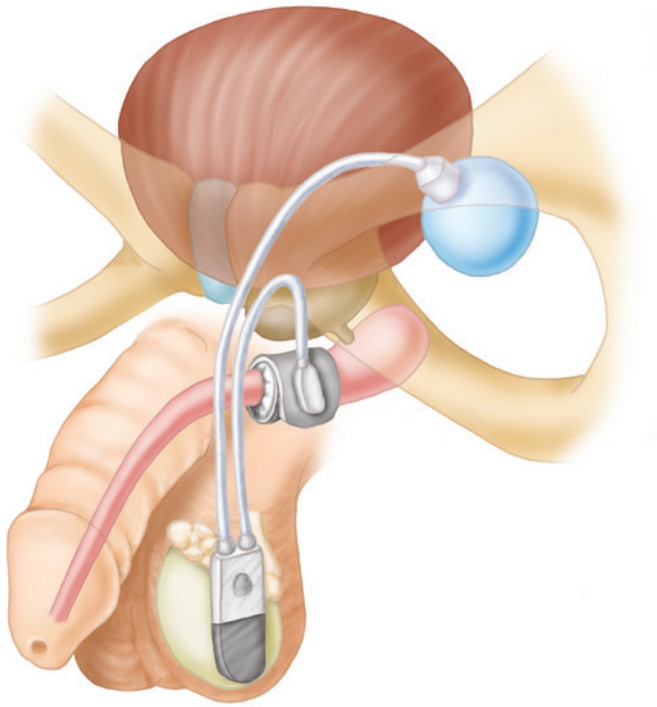


Figure 50.1 Artificial urinary sphincter. (With permission from Trost L, Elliott DS. Male stress urinary incontinence: a review of surgical treatment options and outcomes. Advances in Urology. 2012:2012:289489.)

or midline) is the classic and the preferred approach according to the International Continence Society AUS Consensus group.[9] Others have described placement through a single peno-scrotal incision.[15] Traditionally, after placement of a Foley catheter, a midline perineal incision is made and the bulbospongiosus muscle is exposed. The bulbospongiosus muscle can be split or preserved: It is our practice to split the muscle. The urethra is dissected circumferentially with special attention being given to mobilization of the urethra from the intracrural septum. A 2-cm window is made between the corpora cavernosa and the urethra. The urethra is inspected for injury visually and then by irrigating the urethra. This can be done by injecting normal saline through an angiocath into the urethra alongside the catheter, obviating the need for catheter removal. Alternatively, the Foley can be withdrawn into the distal urethra and saline injected through the catheter while the meatus is compressed. The urethra is then measured, and the appropriate sized cuff is placed.

We use a transverse lower abdominal incision for placement of the reservoir; however, a midline incision is also an option. The reservoir can be placed preperitoneally, intraperitoneally, or in the retropubic space. We retract the rectus muscle medially, open the transversalis fascia, and place the reservoir in the retropubic space. Typically, a 61–70 cm H_2O pressure reservoir is used and filled with 23 mL of saline. The tubing from the cuff is passed over the pubic bone into the suprapubic incision. Finally, a plane is developed between the suprapubic incision and the ipsilateral hemiscrotum, and a pocket is created in a dependent position for the pump. The components are then connected, and the device is cycled and left in the deactivated state.

MALE SLINGS

Male slings have been an active area of research and innovation in the last 20 years and are the most commonly utilized alternative to AUS placement. There have been a variety of slings manufactured in the past that one may encounter in practice today, for example, during a revision surgery. Slings can be divided into fixed slings and adjustable slings (Fig. 50.2). The latter allow for manipulation of the sling post implant. The highest level of evidence of data is available for fixed slings.

Fixed Male Slings

Bone-Anchored Sling. The InVance bone-anchored sling (American Medical Systems, Minnetonka, MN) is no longer commercially available in the United States; however, it remains of interest as one can still see complications of bone-anchored slings. It was designed to compress the bulbar urethra and is affixed to the pubic bone. If confronted with a case for revision, it is important to note the position of the three bone anchors with attached polypropylene suture placed bilaterally in the pubic rami utilizing a drill. The first is placed at the junction of the pubic symphysis and the pubic ramus, the second is placed 3 cm below the first, and the last splits the distance between the two.

Transobturator Sling. The retrourethral transobturator slings (RTSs) theoretically restore continence by repositioning the proximal urethra. Tensioning causes proximal movement of the dorsal portion of the proximal bulb, which in turn affects closure of urethral lumen and advances the membranous urethra cranial and posteriorly.[18] While this theory has been advocated, it is also plausible that the majority of the effect on continence is caused by compression of the proximal bulb. This sling is most effective in men with some degree of retained continence (defined by pad weight or a Valsalva leak-point pressure >100 mm Hg).[19] RTSs have been shown to have a durable success rate with a 53–90% improvement rate after 1–3 years follow-up reported in the literature.[20–24]

The AdVance sling (Boston Scientific Corporation, Marlborough, MA) has become the most commonly used type of male sling since its introduction in the mid 2000s. A Foley catheter is placed, and a midline perineal incision is made. The bulbospongiosus muscle is identified, split in the midline, and dissected off the urethra. The urethra is dissected to the level of the perineal body and genitourinary diaphragm, and the urethra is partially separated from the perineal body. A mark is made on the skin approximately 2 cm below and 1.5 cm lateral to the insertion of the adductor longus. A spinal needle may be used to ensure that the obturator fossa lies at the level of the mark, and a small skin incision is made. A helical passer is passed through the skin, the obturator fossae, the obturator externus muscle, and the obturator membrane. The triangle formed by the urethra, the bulbospongiosus, and the bulbocavernosus muscles is palpated and the trocar is guided onto the index finger. A similar procedure is performed on the contralateral side. Cystoscopy is performed to ensure that there is no injury to the bladder or urethra. The sling is then attached and brought out through the skin. It is secured proximally

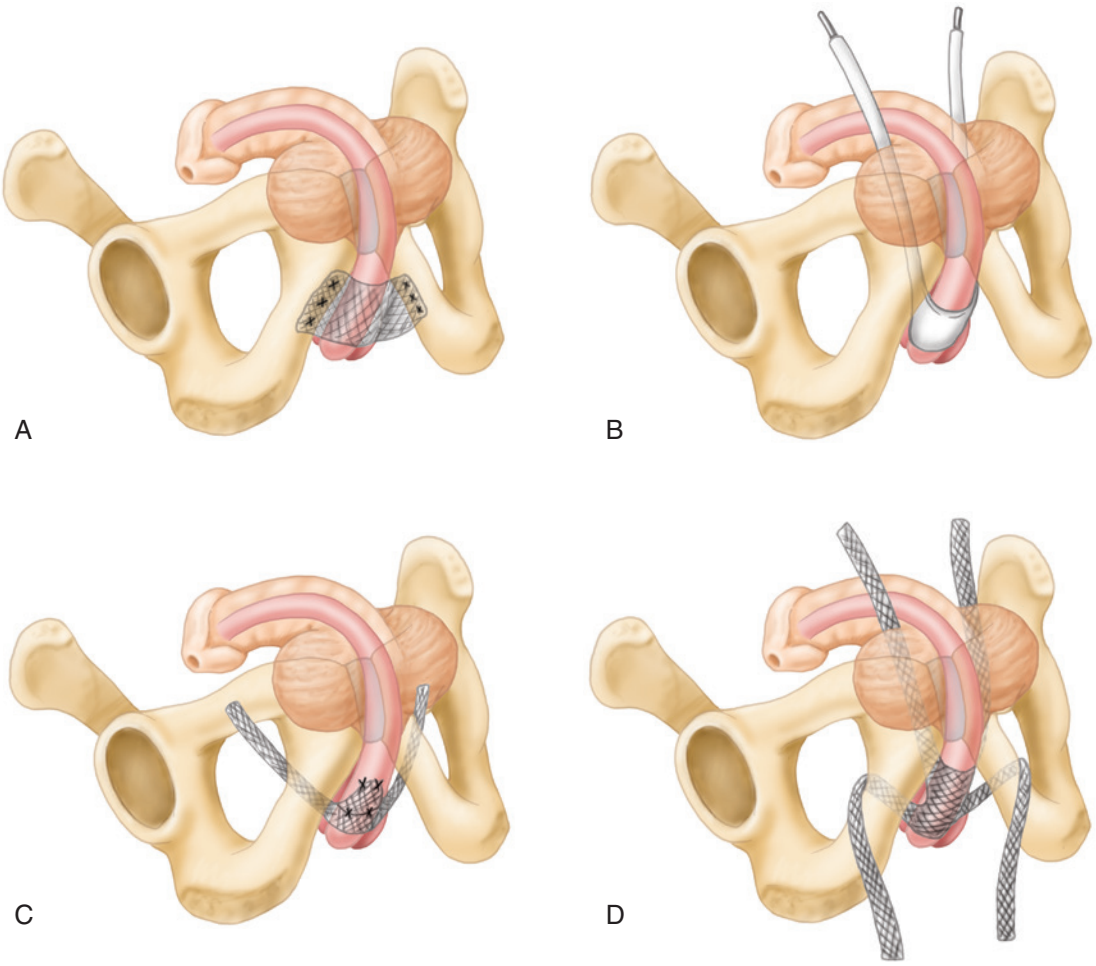


Figure 50.2 Male slings (A-BAS; B-ARS; C-TMS; D-quadratic). (With permission from Trost L, Elliott DS. Male stress urinary incontinence: a review of surgical treatment options and outcomes. Advances in Urology. 2012:2012:289489.)

and distally in the midline with suture, and tension is placed to provide elevation of the urethra. Cystoscopy is repeated to evaluate urethral coaptation.[18]

The I-Stop TOMS (CL Medical, Lyon, France) is commercially available in Europe; however, it is not approved for use in the United States. The procedure is akin to that for the AdVance male sling; however, this sling has two transobturator arms on each side.[25]

Quadratic Sling. The quadratic sling, Virtue sling (Coloplast, Humlebaek, Denmark), was introduced in 2012. Initially the sling was hypothesized to provide improved continence outcomes by generating greater urethral compression than prior slings.[26] The sling causes proximal urethral relocation and bulbar urethral compression. Increased efficacy was found if the sling was fixed to the urethra, preventing loosening in the early postoperative period before it was able to scar into place.[27]

During sling placement, the urethra is dissected from the perineal body while the bulbospongiosus muscle is left intact. Using the sling passer, each arm is passed from the medial aspect of the descending ramus to the ipsilateral groin crease. The prepubic arm introducers are placed from a superior position 2 cm above the pubic symphysis, each 2 cm lateral to midline, and exit at the perineum lateral to the urethra. The four mesh arms are released after appropriate tensioning is performed. The sling can be further fixated by tunneling the transobturator arms back to the midline and suturing them to each other as well as by adding a figure of eight suture at the junction of the rami and pelvis. This fixation approach improved 1-year success rates from 41.9% to 70.9%. Success was achieved in 57.1% of patients with severe incontinence.[27]

Adjustable Male Slings

The data on the relative and absolute efficacy of these slings comprise single-institution descriptive series, with varying inclusion and exclusion criteria and definitions of success.[28] Given the paucity of level one efficacy data,[6,29] the choice of intervention relies on patient and physician preference, which should be informed by the complication profile associated with each of these procedures.

Adjustable Retropubic Slings. The adjustable retropubic sling (ARS) provides suburethral support and is anchored by retropubic mesh arms with reported success rates of 72–85%.[17,30,31] The most commonly used ARS is the Argus adjustable male sling (Promedon SA, Cordoba, Argentina). A specialty needle is used to pass the sling from a perineal incision through the rectus fascia following

immediately inferior to the pubic bone. Under direct visualization with cystoscopy, the sling is adjusted by moving the washers until adequate urethral wall coaptation is appreciated.[30,32]

The Reemex system for placement of the male readjustable sling (Neomedic International, Barcelona, Spain) has also been described in a multinational study by Sousa-Escandon and colleagues.[31] Per their description, a 60-degree modified Stamey needle, loaded with the lateral traction thread, is passed on each side in a retrograde fashion to the level of a suprapubic incision. The threads are then pulled through to place the monofilament sling flush with the bulbocavernosus muscle, and the sling is sutured in place. The threads are placed into a varitensor device. This has an external manipulator that allows for thread adjustments.

Adjustable Transobturator Slings. The adjustable transobturator hydraulic mesh system (ATOMS; AMI, Vienna, Austria) has been available in Europe since 2009[34]. The central silicone cushion is fitted onto the surface of the urethra and bulbospongiosus. Mesh arms are attached to the helical trocar and passed around the inferior pubic ramus. The mesh is then sutured to the proximal end of the silicone cushion to stabilize the system. The titanium port is tunneled over the pubis and placed in a subcutaneous left suprapubic location with two anchoring sutures.[34,35]

INFLATABLE BALLOON COMPRESSION

Prostate Adjustable Continence Therapy (ProACT; Uromedica, Plymouth Minn, Fig. 50.3) has been introduced as a minimally invasive treatment for postprostatectomy incontinence. The ProACT has recently been approved for use in the United States though it has been used commonly in other countries around the world for several years, with 55–68% satisfaction in small contemporary series.[36–38] The patient is placed in lithotomy and 50–100 mL of contrast is instilled into the bladder. Through a perineal incision, a Kelly clamp was previously used to perforate the pelvic floor;[39,40] however, a tissue expansion device now facilitates the development of the periurethral space.[41] Two balloons are then placed beneath the bladder neck, bilaterally dorsal to the urethra. The balloons are filled with 1–5 mL of contrast medium and sterile water. Cystoscopy is performed to confirm balloon position and exclude urethral injury. The balloon ports are placed bilaterally just beneath dartos fascia in the scrotum. This allows for percutaneous needle access for future inflation or deflation of the balloons.[39,40]

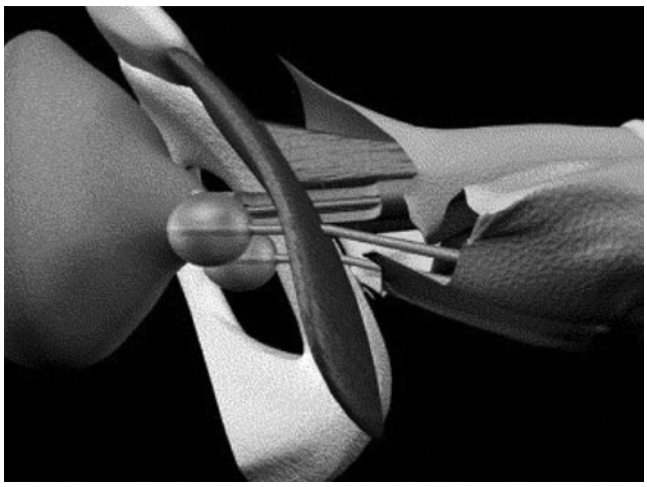


Figure 50.3 ProACT device. Relationship to bladder neck and genitourinary diaphragm. (With permission from Trigo-Rocha F, Gomes CM, Pompeo AC, Lucon AM, Arap S. Prospective study evaluating the efficacy and safety of Adjustable Continence Therapy (ProACT) for post radical prostatectomy urinary incontinence. Urology. 2006;67(5):965-9.)

Intraoperative Complications

ARTIFICIAL URINARY SPHINCTER

Most intraoperative complications are inconsequential if recognized and treated at the time of surgery. The exception to this is an injury to the urethra that requires aborting the procedure in most cases.

Bleeding

Most significant bleeding with AUS placement occurs as a result of a corpora cavernosa or spongiosum injury. Bleeding can also occur with placement of the reservoir from epigastric or retroperitoneal vessels.

Corporal Injury

When performing AUS placement corporal injury can occur during mobilization of the urethra from the intracrural septum. Corporal injury may result in significant bleeding that can impair visualization. Adequate exposure is the key to identifying the injury. Once the injury is identified it can be repaired with absorbable suture.

Urethral Injury

Urethral injury is another potential intraoperative complication, and one that should not go unrecognized. Urethral injury typically occurs dorsally where the spongiosum is thinnest. To detect an unrecognized urethral injury, saline or dilute indigo carmine can be instilled alongside the Foley catheter or through the Foley catheter while moving it in a retrograde fashion. If a urethral injury is identified, it should be repaired in multiple layers with absorbable suture. Most surgeons would abort AUS placement and leave a Foley catheter for an appropriate period of time. In rare cases if the injury is small and away from the intended site of implantation, the cuff can be placed, although this must be done with extreme caution. If there is any question regarding the repair, or if the cuff cannot be placed away from the sight of injury, then the procedure should be aborted. Injury to the corpus spongiosum but not involving the urethra is usually inconsequential, especially when it occurs ventrally where the spongy tissue is thick. Such injuries can simply be oversewn to control bleeding. Dorsally, where the spongiosum is thin, it is common to have a concomitant urethral injury.

Device Injury

Care must also be taken to avoid any injury to the device. Damage to the device can result in leakage of fluid from the

device and mechanical failure. The tubing should be handled with rubber-shod clamps, and care should be taken not to injure the device with sharp instruments or needles. If a device injury is noted, the "injured" component should be replaced. Unrecognized injury will result in device malfunction as fluid leaks out of the system.

MALE SLING

Intraoperative complications with sling placement are unusual, the most common with a bone-anchored sling being bleeding. Based on technique, obturator nerve injury would seem to be a possibility, but has not yet been reported in transobturator and quadratic sling placement.

Bleeding

Significant intraoperative bleeding during male sling placement is rare and none of the major series has reported transfusions.[11,16,17,24,27,42,43] Corporal injury and bleeding can occur during dissection. Bleeding from a main or accessory obturator vessel would be possible with a transobturator sling placement. With transobturator sling placement, it is not unusual to encounter bleeding as the urethra is dissected to the perineal body. It occurs as a result of small injuries to the spongiosum that can be oversewn with a fine absorbable suture (e.g., 4-0 polyglycolic acid). Also with transobturator sling placement, bleeding can occur from injury to small vessels along the route of needle passage through the obturator fossa. When this occurs tensioning of the sling may control bleeding. Injury to a major obturator vessel is possible, but rare.

Urethral Injury

Urethral injury with the bone-anchored sling is not reported in the literature but is certainly possible and should be treated as described above for the AUS.

Romano et al. reported a "potential" urethral perforation rate of 6% with the Argus ARS. This was addressed intraoperatively by repositioning the needle and resulted in no further complications.[30] With transobturator sling placement, urethral injury is rare, though possible from a needle perforation, usually near the bladder neck.[43] Thus cystoscopy after sling placement is essential. If such an injury is seen, the needle or sling should be removed. The injury is usually not in a position that can easily be repaired, so treatment is with catheter drainage for up to 7 days depending on the size of the injury. The sling may be replaced in the same setting at the surgeon's discretion depending on the site and size of the injury.

Early Postoperative Complications

ARTIFICIAL URINARY SPHINCTER

Hematoma

Scrotal hematoma is a common minor postoperative complication associated with AUS implantation. Hematomas typically resolve spontaneously without intervention; evacuation is rarely indicated.

Retention

Another common early complication is urinary retention as a result of postoperative edema.[44] Patients who undergo transcorporal AUS placement are at an increased risk for developing postoperative retention.[45] We sometimes leave a 14Fr Foley catheter overnight in an attempt to avoid this problem. Bladder neck dilatation for anastomotic stenosis is a risk factor for retention beyond 24 hours, secondary to temporary swelling. If retention occurs, the first step should be examination of the device to ensure deactivation with the cuff in an open position. If catheterization is required it should be performed carefully with a small 10–14Fr Foley and catheterization time should be kept to a minimum, preferably under 48 hours.[9,46] Also, if there is even the slightest difficulty in replacing a catheter, it should be done under endoscopic guidance or a suprapubic tube should be placed. If the patient is unable to void after 48 hours suprapubic catheter placement may be considered.[47]

Early Infection

Early infection can occur and may manifest with erythema, induration or edema around the pump, as well as with purulent drainage, fever, or pain in the scrotum, groin, or perineum. Early infection is most typically the result of bacterial contamination at the time of implantation. The most common organism in early infection is *Staphylococcus aureus* and *S. epidermidis*, with increasing rates of methicillin resistance.[48] The introduction of Inhibizone in 2008 was meant to decrease early infections by providing an antibiotic coating. However, the only clinical data published did not show a change in the rates of AUS infections over 4 years of use.[49]

Another potential etiology of early infection is unrecognized urethral injury. Urethroscopy should be performed at the time of device removal.[9] Infection requires removal of the entire device and reimplantation after at least 3 months. In select cases, one may consider replacement at the time of removal, after aggressive wound irrigation with antibiotics as described by Bryan et al.[50]

Early Erosion

Erosion can also occur with or without infection. It is likely the result of unrecognized iatrogenic urethral injury, urethral thinning, or early postoperative replacement of a Foley catheter.[51] Erosion may present with pain or swelling in the scrotum or perineum, pain referred to the tip of the penis, recurrent incontinence, dysuria, hematuria, or bloody discharge. If erosion occurs without infection the tubing can be capped at the time of cuff removal. If associated with infection the entire device should be removed. The urethra is repaired with absorbable suture at the site of erosion and a Foley catheter is left indwelling. A voiding cystourethrogram (VCUG) is performed to ensure that the urethra has healed prior to the removal of the catheter, and at the time of reimplantation a different site is selected for the cuff.

MALE PERINEAL SLING

Hematoma

Postoperative hematoma is a rare event. There is one study reporting 1 of 136 patients affected in a single cohort and

2 of 50 patients in a single BAS cohort. All cases resolved spontaneously.[21,52]

Acute Retention

Retrourethral transobturator slings are associated with a 3–21% risk of postoperative retention, compared to 14% in ARS.[17] In the initial study of the quadratic male sling, there were no occurrences of postoperative retention.[27] Postoperative pain and inflammation may contribute to early urinary retention. In truth, acute retention can be expected in a certain number of cases and is more of an unfavorable early outcome than a true "complication." Retrourethral transobturator slings generally have a higher rate of acute retention, which can take up to 12 weeks to resolve.[17] Sling lysis for protracted retention has been reported, but remains an extremely rare event.[43]

Pain and Paresthesia

Postoperative pain and paresthesia have been reported in all types of male slings and have been the most disappointing aspects of male slings in our experience. They are hypothesized to result from injury to the superficial perineal nerves. Interpretation of the incidence and severity of postoperative pain is limited by the differing criteria and categorization of postoperative discomfort in the literature. For example, from 4% to over 50% of patients reported perineal buttock pain after BAS or RTS in several large cohort studies, although all resolved by 3 months.[16,17,53,54] Notably, Romano et al. reported a 21% rate of dysuria associated with perineal discomfort or moderate pain following placement of the ARS that resolved or became very mild after 1–2 months of analgesic and NSAIDs. Perineal and thigh pain or paresthesias occurred in 68% of patients in the series of adjustable transobturator sling placement by Hoda et al.;[34] however, this pain was also managed conservatively with NSAIDs for up to 4 weeks. Decreasing the adjustment pressure to 45 cm H_20 is also purported to reduce risk of postoperative perineal pain.[30] There are only two cases of reported persistent discomfort after 6 months with conservative management.[27]

Persistent pain should be further evaluated. We obtain a CT and/or bone scan in appropriate cases. In cases of severe or persistent pain consideration should be given to sling removal.

Infection

Early postoperative infection is possible with male slings. Like the AUS, it is probably the result of bacterial contamination at the time of implantation. Infection of the device was more common when silicone coated implants were used. With the advent of polypropylene this has become an unusual complication and most can be managed conservatively. A single series did report early post-infection requiring explant in 4 of 99 patients.[34] Although early infection remains rare in the literature, BAS were the most likely to be associated with early infections.[17] A single perineal incision has been associated with significantly fewer early skin infections in ARS placement compared to a dual incision approach in a prospective study comparing 36 consecutive patients.[33]

INFLATABLE BALLOON COMPRESSION

Acute urinary retention has been reported in 1–6% of patients after ProACT placement. Treatment consisted of withdrawing a small amount of solution from the balloons via the injection ports. Infection, erosion, and balloon migration and rupture have also been reported, but the time to occurrence was not specified.[36,39–41] They will be discussed under delayed complications.

Delayed and Long-term Complications

ARTIFICIAL URINARY SPHINCTER

The majority of delayed AUS complications require a surgical intervention, either revision or explant. The rate of repeated surgical intervention has been reported as 31–53% in large contemporary series following patients for over 5 years.[55–57] Thus the known revision rate of 4–5% per year after implantation should be explained to the patient.

Infection and Erosion

Rates of infection reported in large series range from 0% to 14%.[55,58–62] Most report higher infection rates in patients' status post–pelvic radiation, including a systematic review of 15 studies.[46,63–65] In contrast to early infections, in which the most common cultured pathogens are skin flora, late infections, those occurring >4 months after implantation, are thought to be the result of hematogenous seeding secondary to bacteremia from another source.[47,66] Late infections most commonly present with scrotal pain, but may also present with erythema, edema, or induration around the pump or fever. Infection is most commonly managed by removing all components of the device; however, management of patients with a salvage technique similar to that used for salvage of penile prostheses has been described.[43] Cystoscopy is performed to rule out urethral erosion. All prosthetic parts are removed, wounds are copiously irrigated according to a seven-solution protocol, and a new device is implanted.[50]

Erosion rates ranging from 2.2% to 6.5% have been reported with a median time to erosion of 20 months.[55,58–61] Common causes include prolonged catheterization,[51] catheterization without cuff deactivation, or repeated endoscopic manipulation of the urethra. Patients at a higher risk for erosion include patients with a history of hypertension and coronary artery disease, as well as prior radiation, prior AUS revision (especially for erosion), and prior urethral stent.[61,67] One patient cohort study spanning 30 years did not find any preoperative risk factors for erosion.[56] Patients undergoing revision for erosion are at risk for worse postoperative continence rates than those undergoing revision for other reasons.

Potential manifestations of urethral erosion include pain or swelling in the perineum or scrotum, pain referred to the tip of the penis, recurrent incontinence, dysuria, hematuria, or bloody discharge. Erosion is typically into the urethra, but erosion of tubing to the skin can also occur. Urethral erosion typically occurs on the dorsal side of the urethra

where the spongiosum is thinnest, but can occur anywhere, especially if associated with trauma (Figs. 50.4 and 50.5). When urethral erosion occurs, at a minimum, the cuff has to be removed. If there is any suspicion of associated infection, the entire device should be removed. The site of erosion may be repaired with absorbable suture if it can be easily accessed. Dorsal erosions are the most common and are often left unrepaired and simply allowed to heal with a period of catheterization; however, immediate urethral repair has been shown to decrease the risk of stricture formation and increase the likelihood of AUS reimplantation.[68] In either case a Foley catheter is left indwelling until closure, which is evidenced by voiding cystourethrogram after 1–2 weeks. Reimplantation is performed 3–6 months later. Prior to reimplantation, cystourethroscopy is performed to ensure adequate healing and to rule out formation of a stricture at the site of previous erosion. The new cuff is positioned away from the erosion site. Transcorporal cuff placement[69] and utilization of biologic grafts can help buttress the urethra and decrease the recurrence of erosion.

Recurrent Incontinence

Recurrent incontinence can be due to bladder or sphincteric dysfunction. If it is due to sphincteric insufficiency then it is likely related to urethral atrophy or mechanical malfunction of the device, as discussed below. Recurrent incontinence can also be a manifestation of infection or erosion as previously discussed. If it is not clear whether the incontinence is due to bladder or sphincteric dysfunction, then urodynamic evaluation can be helpful. When performing urodynamics in a patient that has an AUS, the device should be deactivated with the cuff deflated prior to inserting the catheter. Once the catheter is in place, the AUS should be reactivated for filling and stress testing.

Urethral Atrophy. The introduction of the narrow-backed cuff has improved urethral pressure transmission; however, urethral atrophy still accounts for a significant portion of nonmechanical AUS revisions.[56] Rates of urethral atrophy have been reported ranging from 0% to 14%,[56,58–61] which vary with length of follow-up.

Urethral atrophy manifests as new-onset incontinence. Exam demonstrates a normally functioning pump. Cystourethroscopy may reveal incomplete coaptation of the urethra, and the urethra may appear thin and pale. Multiple management options have been proposed for urethral atrophy including downsizing of the cuff,[70] placing the cuff in a more proximal location,[71] placement of tandem cuffs,[72] increasing reservoir pressure, or transcorporal placement of the cuff.[69] Downsizing of the cuff has become a more effective management option since the introduction of the 3.5-cm cuff, which addresses urethral thinning, in addition to the decreasing caliber of the proximal urethra, allowing for cuff placement around the unaffected portion of the urethra.[73] In addition one report demonstrated that in patients who deactivated their cuff at night, recurrent incontinence secondary to urethral atrophy was decreased from 21% to 10%.[74]

It is our preference to downsize the cuff if possible as the first-line treatment for urethral atrophy. A second choice would be to move the cuff to another position, usually proximally. Placing a transcorporal cuff is also a good option in cases where adequate urethral circumference cannot be obtained. Rahman et al. have also described wrapping the urethra with a biologic material to increase bulk.[75] Cadaveric studies have shown the use of additional cuffs do not improve leak point pressure and one should rather focus on proximal placement of the device to achieve complete urethral coaptation.[76]

Mechanical Malfunction. Mechanical malfunctions can include leakage from one of the components, kinking of the tubing, pump malfunction, and connector separation. Reported rates of mechanical malfunction in large contemporary series range from 6% to 25.3%.[56,58–61] A greater than 50% decrease in mechanical failure rates has been attributed to improvements in the material used to make the AUS and introduction of the narrow back cuff.[59] Mechanical malfunction typically presents with recurrent incontinence, but can also present with urinary retention. Physical exam often reveals a pump that is difficult to compress, one that is partially decompressed, or one that takes too long to refill. Pelvic ultrasound (US) can also be used to measure the volume of the reservoir to assess for a leak. Using preoperative US was 100% sensitive and specific when used in determining fluid status. When pressure regulating balloon (PRB) was full, management consisted of cuff downsizing, transcorporal cuff placement, and total removal/replacement. In all cases of device leak, an entire removal/replacement was performed.[77] Intraoperative methods of evaluating component leakage including Ohm testing and volumetric-pressure measurements are available. If a component-specific malfunction is identified, the component can be replaced. If the problematic site (e.g., point of leakage) cannot be found or the device is more than 5 years old, removal and replacement of all components should be done.

Urinary Retention

Urinary retention that presents as a late postoperative complication requires endoscopic examination to evaluate the AUS and the bladder neck for contracture or urethral stricture. The latter two are usually the result of prostate surgery and not the AUS per se, but these, nevertheless, need to be checked. Difficulty voiding or retention can also be a sign of an AUS erosion or late infection. Retention may also be the result of mechanical malfunction.

MALE SLING

Infection and Erosion

The rate of infection is as high as 15% for BAS, compared to 4–6% for ARS, 0–3% for RTS, and 0% for the quadratic sling in its initial trial.[27,78] None of the cohorts in this systematic review reported urethral erosion with BAS or RTS, although there was a 1.9% and 12% rate of erosion with the Reemex system and Argus ARS, respectively (Figs. 50.6 and 50.7).[78] The most recent series involving the Reemex system reported a 4.7% rate of late infection and no urethral erosions in 64 patients.[79] In the most mature cohort in the literature, there were no instances of infection or erosion with the RTS after 3 years of follow-up.[80] In our experience with BAS, patients most commonly present at



Figure 50.4 Urethral erosion of artificial urinary sphincter – cystoscopic view; color indicates that this is likely a longstanding erosion.

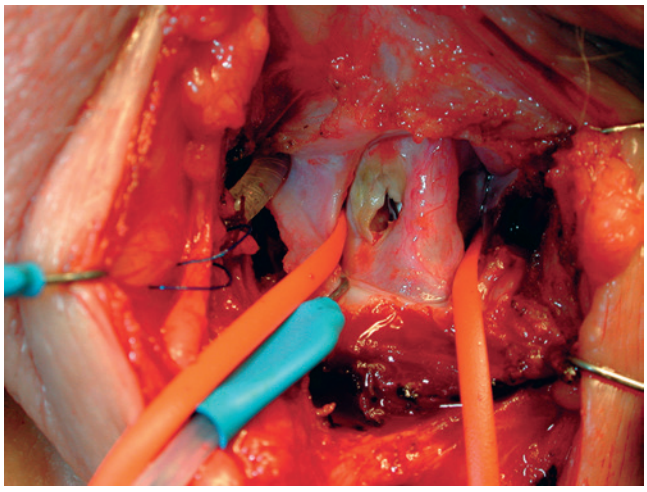


Figure 50.5 Urethral erosion of artificial urinary sphincter – gross view.

6–9 months postoperatively. We have noted that patients with infection often present with chronic, low-grade symptoms including mild perineal pain or swelling or a sinus tract that intermittently drains small amounts of fluid (Fig. 50.8) as opposed to acute or systemic symptoms. We have seen patients present with chronic infections and draining sinus tracts in slings implanted years ago. There are no defined risk factors for sling infection or erosion,[47] including pelvic radiation, which is conversely associated with poor outcomes after AUS placement. However, we recommend careful counseling of the potentially increased risks prior to sling placement, especially as there is evidence that a history of radiation leads to decreased efficacy of male slings.[24]

Removal of the sling is the typical treatment of infection or erosion. However, we have found that despite infection some patients are very reluctant to undergo sling removal secondary to improvement in their continence. We attempted salvage of the sling in two of these patients using the irrigation protocol previously described for salvage of the AUS.[50] This was unsuccessful and both slings subsequently required removal. In addition, we have one patient who was managed with intermittent antibiotics and fulguration of a chronic sinus tract for more than 10 years due to his reluctance to have the sling removed. The infection eventually resolved clinically with resolution of the sinus tract.

De Novo Urgency

To our knowledge, de novo urgency was first described in our series after one patient (1.6%) developed de novo urge incontinence 6.5 months post placement of a BAS.[11] It is theoretically caused by an increase of bladder outlet resistance by compression of the bulbar urethra. De novo urgency has since been reported in up to 14% of BAS placements, although it has not been reported in other sling types.[17] De novo urgency should always be evaluated to rule out possible obstruction or recurrent stress incontinence. Uroflow and post-void residual may be used; however, if definitive diagnosis is required urodynamic testing may be used. If there is no evidence of obstruction then a trial of anticholinergics is recommended. In one series, a patient underwent sling lysis for refractory symptoms.[52]

Obstruction

Iatrogenic obstruction following placement of a male sling is rare but not impossible. Prolonged postoperative retention has been described in 7–8% of patients following RTS, managed conservatively or with sling lysis.[80,81] No new episodes were seen to occur after the first year.[80]

To address obstruction and maintain some improvement in continence, the sling can be loosened. The sling can be isolated in the midline and partially cut (Fig. 50.9). Alternatively, or if this does not help, the sling can be completely transected. Other options for sling revision include removal and replacement of the sling or releasing one side of the sling and replacing sutures more laterally on the sling. In our experience, the latter has not been an option because the excess sling has typically been excised at the time of sling placement.

Prolonged Pain and Paresthesia

The majority of patients have perineal pain after placement of a bone-anchored sling; however, most published series have reported resolution of the pain 3–4 months postoperatively.[16,53] We found that 8.1% of patients experienced prolonged (>3 months) paresthesia or perineal pain.[11] In addition, Fassi-Fehri et al. reported a 12% occurrence of prolonged pain requiring analgesic management.[52] In our experience, patients with prolonged paresthesia following bone-anchored slings typically located the symptoms to the scrotum and those who had prolonged pain experienced it in the perineum. The majority of our patients were managed effectively with watchful waiting and antiinflammatory

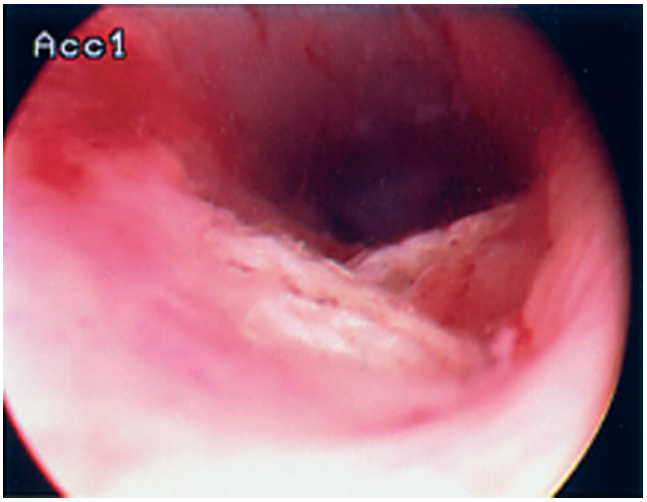


Figure 50.6 Eroded male sling – cystoscopic view.



Figure 50.8 Infected male sling with granulation tissue and sinus tract.

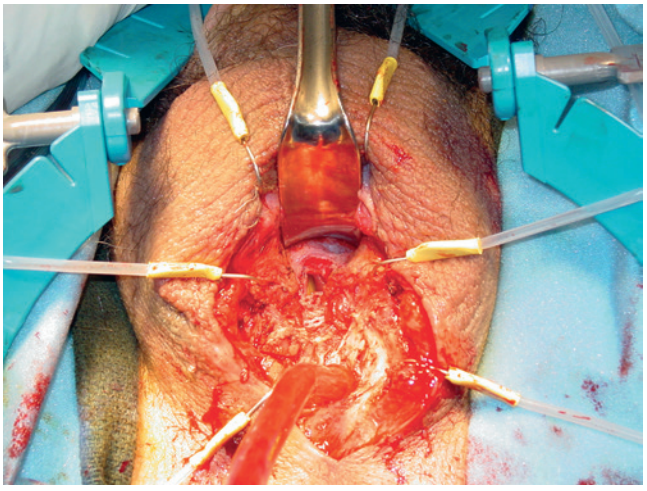


Figure 50.7 Eroded male sling – surgical view.

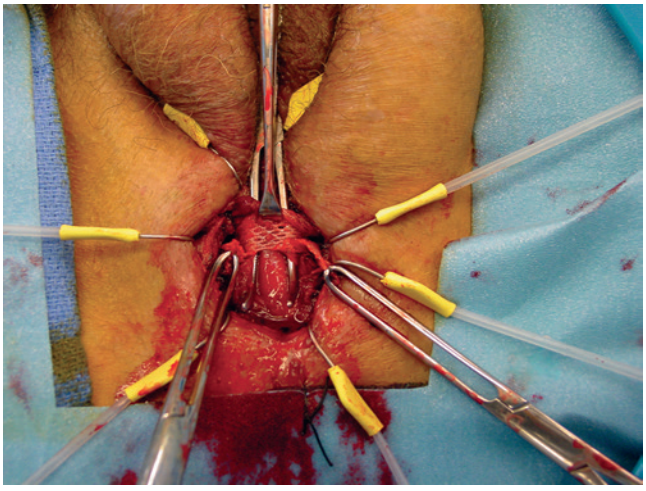


Figure 50.9 A right angle was placed between the intact sling and the urethra and the sling was cut until tension was relieved.

medications. However, in patients with severe persistent pain we obtain a bone scan and a CT scan to evaluate for osseus or infectious complications. Pain can be a manifestation of sling infection. One patient in our series had persistent pain severe enough to require removal of the sling. Despite unremarkable imaging, the sling was infected at the time of removal.

Similarly, persistent pain following retropubic sling placement is very rare; to our knowledge, only two studies report pain >3 months – 5–6% prolonged pain following ARS placement and 3% prolonged pain following RTS.[17,82]

Osseus Complications

There is a potential for risk for osseus complications after bone-anchored sling placement. There is no report in the English literature of such an occurrence; a single case report was described in the French literature[83].

Recurrent Incontinence

Following a bone-anchored sling, recurrent incontinence should be evaluated with urodynamics and a pelvic radiograph should be obtained to evaluate for bone anchor dislodgement. Comiter reported bone anchor dislodgement in 4.2% (2/48) of patients. In their series, patients presented with recurrent incontinence, screw dislodgement was confirmed with pelvic radiograph, and successful sling revision was performed.[16] When bone anchor dislodgement is not the etiology of recurrent stress incontinence, other treatment options include bulking agents, repeat male sling placement (if it is thought that compression is not adequate), or placement of an AUS.

Recurrent incontinence following an ARS is managed with a retightening procedure. Rather than a complication of the procedure, this is precisely what the adjustment mechanisms are provided for. Utilizing the Reemex system, this can be accomplished on an outpatient basis. Patients with a history of radiation are more likely to require an adjustment[17,79,84].

Conclusions

The artificial urinary sphincter, male sling, and ProACT balloon compression (not currently available in the United

States) are the current surgical treatment options for sphincteric insufficiency following prostate surgery. Each has acceptable complication rates that can be minimized with attention to detail and meticulous surgical and aseptic technique. Patients should be informed of the potential complications associated with the procedures. Along with more minor complications, the AUS, male sling, and the ProACT balloon compression device each have a risk of infection and erosion that can result in the need for explantation. In addition, the AUS is a mechanical device that inherently carries a risk of mechanical malfunction and the need for device revision or replacement. Although it is typically not severe, patients undergoing male sling placement should also be made aware of the possibility of prolonged pain and/or paresthesia. Patients who understand their treatment options and are well-informed regarding potential risks and complications are more likely to be satisfied following surgery.

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Chapter 50 Questions

1. What is most common area of injury to the urethra during artificial urinary sphincter (AUS) insertion?
   a. Dorsal bulb
   b. Ventral bulb
   c. Lateral at the perineal body
   d. Membranous urethra
   e. Medial at the perineal body

2. A substantial injury is made in the proximal urethra, near the site of cuff implantation, during AUS placement. What is the best next step in management?
   a. Abort the case
   b. Repair the urethra and abort the implantation of the device
   c. Repair the urethra and implant the device
   d. Convert to male sling
   e. Consult general surgery

3. A 64-year-old man presents with dysuria 2 months after AUS insertion. Urine analysis is negative and cystoscopy shows no evidence of erosion. The next step is:
   a. Watchful waiting
   b. Antibiotics
   c. Deactivation of the device
   d. Removal of AUS cuff
   e. Removal of all AUS components

4. A 54-year-old man presents 6 months after tranbsobturator male sling placement complaining of bothersome frequency and urgency that he did not experience prior to surgery. The next most appropriate step is:
   a. Antibiotics
   b. Anticholinergic
   c. Uroflow and post-void residual (PVR)
   d. Loosening of the sling
   e. CT scan

5. A 67-year-old male 14 months following an AUS presents with urinary retention. Which of the following is the most appropriate next step?
   a. Renal US
   b. Cystoscopy
   c. Insert Foley
   d. CT scan
   e. Assess for mechanical malfunction of pump

6. A 67-year-old male 14 months following an AUS presents with scrotal erythema, swelling, and pain around the pump of 3 days evolution. Which of the following is the most appropriate next step in management?
   a. CT scan
   b. Scrotal sonogram
   c. Watchful waiting
   d. Renal bladder ultrasound
   e. Surgical exploration of device

7. Which of the following has been shown to be associated with poorer outcomes after AUS insertion?
   a. Diabetes mellitus
   b. Hypertension
   c. Obesity
   d. Urethral stricture
   e. History of radiation therapy to pelvis

8. A 62-year-old male patient presents with complaints of gradually worsening incontinence 6 years after AUS insertion. Physical examination reveals the pump in a dependent position and no signs of infection. Cystoscopy reveals no erosion. AUS revision is performed and urethral atrophy is identified. What is the best next step in management?
   a. Insertion of male sling
   b. Increase pressure in pressure regulating balloon
   c. Place tandem cuffs
   d. Downsize the cuff
   e. Replace the entire AUS

9. A 69-year-old male patient, 4 years post AUS insertion, presents with scrotal swelling, pain, and urinary retention. Cystoscopy reveals erosion of cuff into the urethra. Purulent material is found around the device. What is the best next step in management?
   a. Watchful waiting
   b. Removal of the cuff with capping of the tubing and repair of the urethra
   c. Removal of the cuff with capping of the tubing without repair of the urethra
   d. Removal of the entire device with repair of the urethra
   e. Removal of the entire device without repair of the urethra

10. A patient with postprostatectomy incontinence and erectile dysfunction 6 years post AUS insertion presents with gradually worsening incontinence. Surgical exploration reveals severe urethral atrophy, and the circumference of the urethra measures 3 cm. What is the best next step in management?
    a. Watchful waiting
    b. Moving the cuff to a more distal position
    c. Moving the cuff to a more proximal position
    d. Transcorporal cuff placement
    e. Abort the procedure

Cases Studies

CASE 1

A 59-year-old male 2 years post AUS placement presents for follow-up complaining of recent onset of recurrent urinary incontinence. On physical exam, stress incontinence is demonstrated with cough and the device cycles appropriately.

1. The next step in management of this patient is:
   a. Cystoscopy
   b. CT scan
   c. Surgery to reposition or downsize the cuff
   d. Surgery to remove and replace the AUS
   e. Watchful waiting



Case Figure 50.1

Cystoscopy is performed and reveals the following (Case Fig. 50.1). The cuff is removed and a Foley catheter is left in place. The patient returns for follow-up 2 weeks later.

2. The next step in management is:
   a. Removal of Foley catheter and follow up in 2 weeks
   b. Cystoscopy
   c. Voiding cystourethrogram (VCUG)
   d. Urodynamic evaluation
   e. Schedule patient for Foley removal in >2 weeks

VCUG reveals that the urethra is healed and the Foley catheter is removed. Cystoscopy 3 months later reveals a well-healed urethra without evidence of stricture. The patient subsequently undergoes AUS replacement. Three months after AUS activation, the patient complains of persistent incontinence and is wearing 1–2 pads per day. Urodynamic testing reveals the following (Case Fig. 50.2).

3. An appropriate treatment option at that time would include:
   a. Removal of AUS
   b. Placement of tandem cuff
   c. Downsizing the cuff
   d. Clean intermittent catheterization
   e. Trial of anticholinergic therapy

CASE 2

A 67-year-old male presents with recurrent incontinence 16 months after placement of a transobturator male sling. The incontinence is mixed stress and urgency.

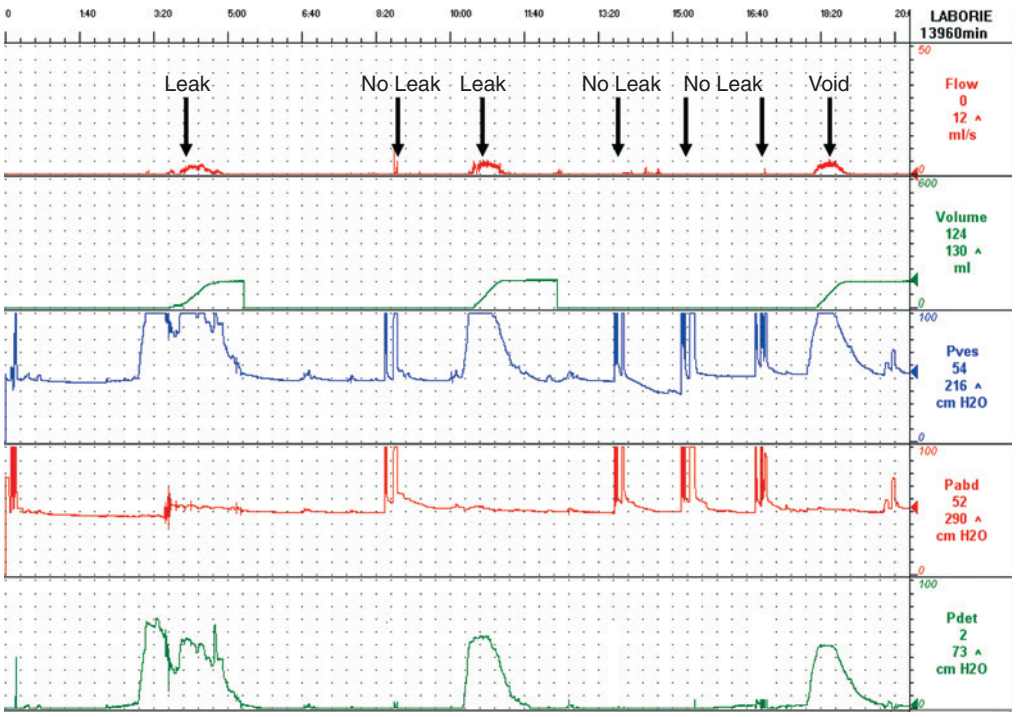
1. The best next step is:
   a. Urodynamic testing
   b. Sling revision
   c. Injection of bulking agent
   d. Repeat sling procedure
   e. AUS

2. According to the tracing in Case Fig. 50.3 the recurrent incontinence is:
   a. Due to detrusor overactivity
   b. Related to impaired compliance
   c. Stress incontinence
   d. Unable to be characterized by the above study
   e. Overflow incontinence

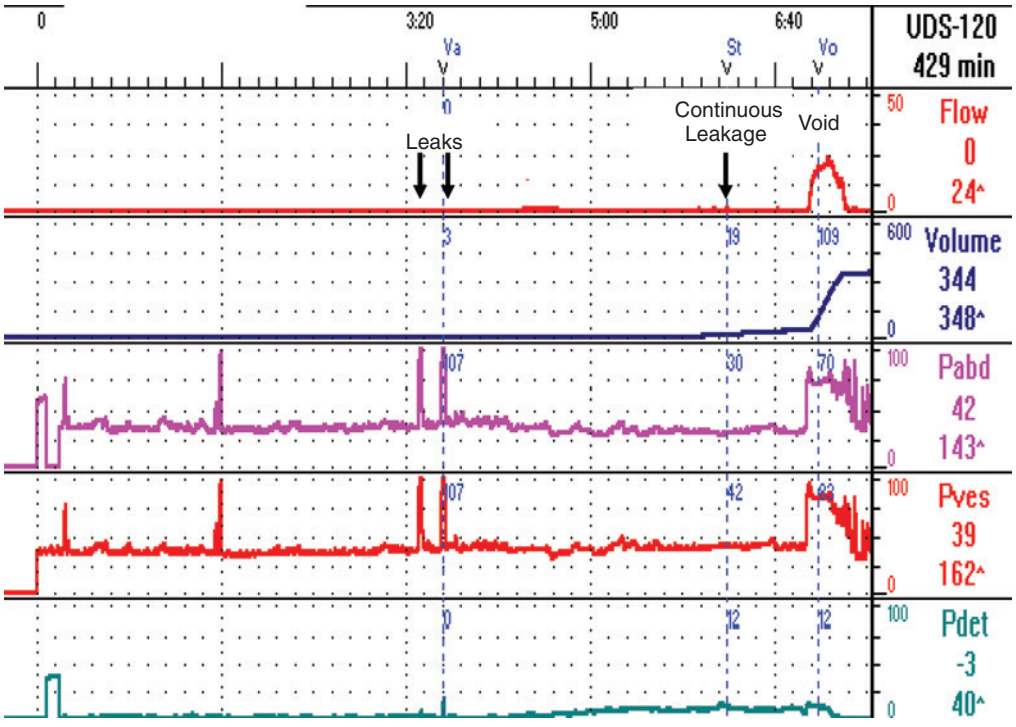
3. Which of the following is the most appropriate next step?
   a. Anticholinergics
   b. CT scan
   c. Repeat sling procedure
   d. AUS
   e. Remove the sling

Answers

1. **a.** Urethral erosion typically occurs on the dorsal side of the urethra where the sponge is thinnest, but can occur anywhere, especially if associated with trauma.
2. **b.** In rare cases if the injury is small and away from the intended site of implantation, the cuff can be placed, although this must be done with extreme caution. If there is any question regarding the repair, or if the cuff cannot be placed away from the sight of injury, then the procedure should be aborted.
3. **a.** Romano et al. reported a 21% rate of dysuria associated with perineal discomfort or moderate pain that resolved or became very mild after 1–2 months of analgesic and NSAIDs.
4. **c.** De novo urgency should always be evaluated to rule out possible obstruction or recurrent stress incontinence. Uroflow and PVR may be used; however, if a definitive diagnosis is required urodynamic testing may be used. In one series, a patient underwent sling lysis for refractory symptoms.[52]
5. **e.** If retention occurs, the first step should be examination of the device to ensure deactivation with the cuff in an open position.
6. **e.** Infection requires removal of the entire device and reimplantation after at least 3 months. In select cases, one may consider replacement at the time of removal, after aggressive wound irrigation with antibiotics as described by Bryan et al.[50]
7. **e.** Pelvic radiation is conversely associated with poor outcomes after AUS placement.
8. **e.** If the problematic site (e.g., point of leakage) cannot be found or the device is more than 5 years old, removal and replacement of all components should be done.
9. **d.** If erosion occurs without infection the tubing can be capped at the time of cuff removal. If associated with infection the entire device should be removed. The urethra is repaired with absorbable suture at the site of erosion and a Foley catheter is left indwelling.



Case Figure 50.2



Case Figure 50.3

10. **d.** It is our preference to downsize the cuff if possible as the first-line treatment for urethral atrophy. A second choice would be to move the cuff to another position, usually proximally. Placing a transcorporal cuff is also a nice option in cases where adequate urethral circumference cannot be obtained.

CASE 1

1. **a.** Cystourethroscopy should be performed to inspect the urethra for signs of atrophy or erosion. This may reveal incomplete coaptation of the urethra, and the urethra may appear thin and pale.
2. **c.** A VCUG is performed to ensure that the urethra has healed prior to removal of the catheter.
3. **e.** If there is no evidence of obstruction, then a trial of anticholinergics is recommended.

CASE 2

1. **a.** De novo urgency should always be evaluated to rule out possible obstruction or recurrent stress incontinence. Uroflow and PVR may be used; however, if definitive diagnosis is required urodynamic testing may be used.
2. **a.** Detrusor overactivity is when involuntary detrusor contractions occur during the filling cystometry. These contractions cannot be suppressed by the patient.
3. **a.** If there is no evidence of obstruction, then a trial of anticholinergics is recommended.

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51 Complications of Urethral Reconstruction

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CHAPTER OUTLINE

Complications of Urethral Stricture Disease
Complications of Diagnostic Procedures
Complications of Urethral Dilation
Complications of Internal Urethrotomy
Complications of Endoscopic Treatment of Posterior Urethral Injuries
Complications of Urethral Stents
Complications of Open Surgical Procedures
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Excision and Primary Anastomosis for Posterior Disruptions
Excision and Primary Anastomosis for Proximal Anterior Strictures
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Flap Reconstruction
Graft Reconstruction
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Chapter 51 Questions and Answers

KEY POINTS

1. The evaluation of urethral stricture disease, prior to treatment, generally includes urethroscopy, a retrograde urethrogram, a voiding cystourethrogram, and bougie calibration for distal disease. Treatment with dilation using a cystoscope or other instruments should not be performed before a complete evaluation and a discussion of all options with the patient.
2. Stricture recurrence is the most common complication of dilation or direct vision internal urethrotomy (DVIU). Because the recurrence rate is high after repeated endoscopic management, the standard of care is generally open reconstruction after a failed dilation or DVIU.
3. Factors that favor the successful outcome of a urethral reconstruction with excisional repair include spatulation of the proximal and distal ends to 30Fr after scar excision and a tension-free anastomosis.
4. Factors that are associated with complications of tissue transfer urethral reconstruction include the use of hirsute skin, mobilization of flaps with compromise to the blood supply, and/or inadequate fixation of a graft to the recipient bed.
5. Strictures associated with lichen sclerosis should not be managed "conservatively" with distal dilations because without relief of the distal obstruction, there can be progression from distal to panurethral stricture disease.

Complications of Urethral Stricture Disease

Observation is always a management option, and the potential complications of observation must be discussed when patients are counseled and giving informed consent. Patients often present with obstructive voiding symptoms, and it would be a mistake for a patient to conclude that having to live with obstructive voiding symptoms would be the only potential drawback of observation.

Distal obstruction is associated with high-pressure voiding. The bladder compensates by thickening with the development of trabeculation, and the urethra proximal to the obstruction can become distended (Fig. 51.1). High-pressure voiding through the prostatic urethra can be associated with extravasation of urine in retrograde fashion into the prostatic ducts. In a physiologically normal patient, extravasation of contrast material into the prostatic ducts is not seen during retrograde urethrography, but this finding is not uncommon in patients with strictures. Retrograde flow of urine through these ducts can lead to complications such as recurrent prostatitis or epididymitis. Eventually, diverticular formation and/or bladder decompensation can develop with an increased capacity and residual or urinary retention. Secondary reflux with or without associated recurrent pyelonephritis can also occur. Ultimately, although it is not common, acute or chronic renal failure can develop as a complication of untreated stricture disease.



Figure 51.1 Markedly dilated posterior urethra proximal to a narrow-caliber bulbar stricture seen on voiding cystourethrography.



Figure 51.2 Lichen sclerosis can manifest with whitish skin color changes and meatal stenosis (A) or with a more severe deformity including a total loss of the coronal sulcus and loss of penile length and girth (B).

In patients with *lichen sclerosis* (LS), also known as *balanitis xerotica obliterans* (BXO), a disease of the penile skin, glans penis, and urethra (Fig. 51.2), stricture progression is common. The obstruction is generally initially within the distal urethra. Often, extravasation into the periurethral glands of Littre is seen during urethral imaging studies in patients with LS (Fig. 51.3), and it is thought that the



Figure 51.3 Retrograde urethrography with extravasation into the periurethral glands of Littre.

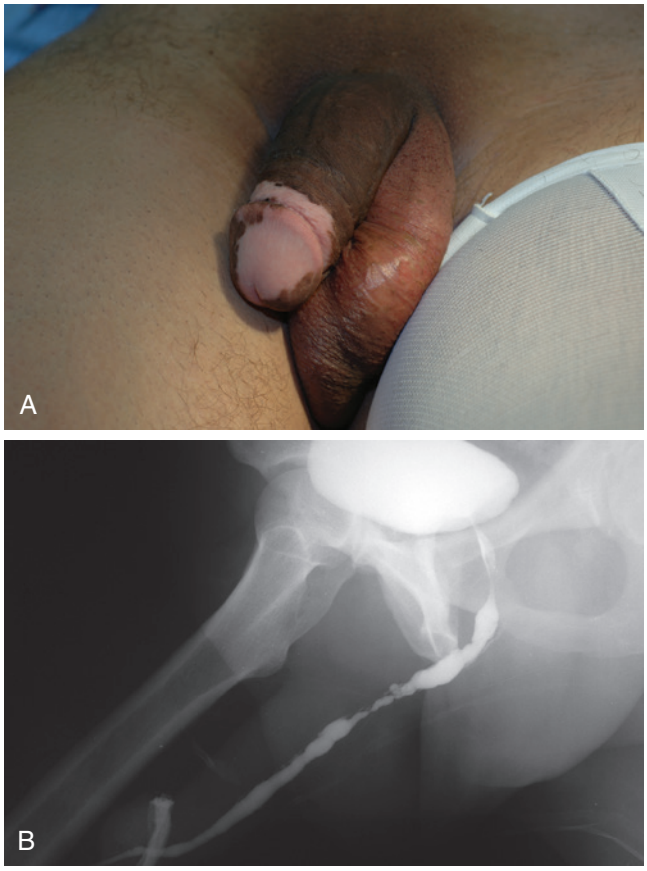


Figure 51.4 (A) Appearance of the penis and (B) retrograde urethrography of the same patient with lichen sclerosis.

extravasation of urine into the periurethral glands may be associated with proximal stricture progression. It is not at all unusual for patients with LS who are conservatively managed to undergo their first retrograde urethrogram and be diagnosed with a >20-cm panurethral stricture (Fig. 51.4). Patients who are clinically diagnosed with LS on physical examination and who have stricture disease limited to the distal urethra are best managed with open staged urethral reconstruction or extended meatotomy.[1,2] In summary, the complications of treatment with observation include, but are not limited to, prostatitis, bladder

decompensation, urinary retention, secondary vesicoureteral reflux, pyelonephritis, renal deterioration, and stricture progression in addition to obstructive symptoms.

Complications of Diagnostic Procedures

Diagnostic testing procedures for known or suspected urethral strictures include urethral calibration with bougie à boule, urethroscopy, retrograde urethrography (RUG), and voiding cystourethrography (VCUG). Bougie calibration, properly performed to assess the caliber of the urethral meatus and fossa navicularis, does not dilate the urethra and therefore is generally not associated with complications. When urethroscopy is performed, the most common complication is urethral trauma. This trauma is intentional when scope dilation is performed in an effort to visualize the stricture in its entirety and enter the bladder. This situation represents treatment with dilation before the extent of the stricture is first assessed and the patient is informed of all treatment options. Should the patient be a candidate for open repair, the operation must be delayed for several months following scope or other dilation because open reconstruction is best performed when the stricture is mature and stable.

Urethral contrast imaging is necessary to assess the length and exact location of the stricture because urethroscopy usually identifies only the distal aspect of the disease. Complications of urethral imaging include urinary tract infection with or without sepsis and extravasation. Urine studies should be performed prior to imaging to ensure the urine is sterile, or allow time for treatment if bacteriuria is present. Improperly performed studies can be associated with a higher complication rate. At our institution, diagnostic testing is performed with flat plate imaging, and this includes both RUG and VCUG. The patient is placed in the oblique position. After a scout film is obtained, gauze is wrapped around the coronal sulcus and the penis is placed on stretch. A 60-mL syringe connected to a cone-shaped adaptor is placed into the urethral meatus to form a seal, and RUG is performed during the injection of contrast material. The bladder is then slowly filled in a retrograde fashion similarly until the patient has the urge to void. VCUG is performed while the patient is voiding.

Extravasation into the corpus spongiosum or venous system is rare when contrast material is instilled gently. However, this complication can occur (Fig. 51.5). Sepsis is a concern with extravasation, and when extravasation occurs, prophylactic antibiotics are given. When imaging is performed with alternative techniques at radiology imaging centers, we have observed a high complication rate related to poor technique.

Often RUGs are performed with catheter insertion into the urethra and inflation of a balloon within the urethra and subsequent contrast injection through the catheter. We measured the caliber of the balloons of 12 to 16Fr catheters after inflation with 1–3 mL of water. With only 2 mL of inflation, the caliber of the balloon was >50Fr (Fig. 51.6), and even 1 mL creates a 39Fr caliber balloon. The caliber of the penile urethra is approximately 30Fr, except for the glans and fossa navicularis, which are generally <25Fr in caliber, and this painful RUG technique often dilates and traumatizes normal urethra. Forceful attempts to insert a catheter through a stricture will both compromise the diagnostic value of the study and damage the urethra (Fig. 51.7).



Figure 51.5 Extravasation into the corpus spongiosum and venous system during retrograde urethrography injection.

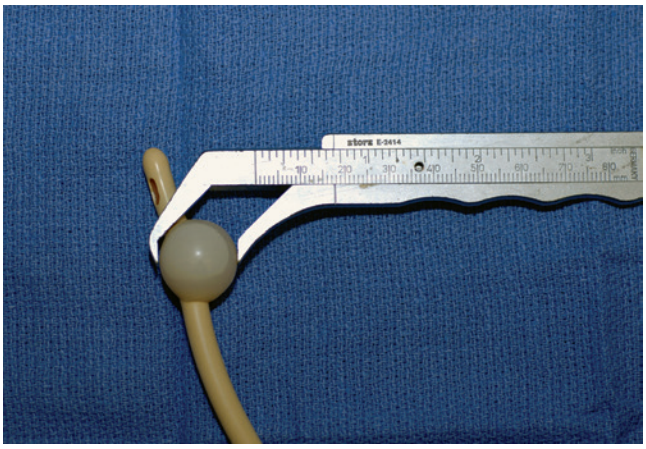


Figure 51.6 Foley catheter after balloon inflation with 2 mL of water. The caliber is >50Fr (1.7 cm diameter).

In addition, errors in technique are associated with an incorrect diagnosis of the length and location of the strictures, and this misdiagnosis can compromise subsequent treatment. For example, if the films are taken when the patient is not in the oblique position, the length of the stricture can be significantly underestimated (Fig. 51.8). Furthermore, if the penis is not on stretch, the length of the stricture will likely be underestimated.

When RUG is performed, the normal posterior urethra is coapted and narrowing in this area is a normal finding. Any disease of the posterior urethra cannot be diagnosed or excluded from the injection film. During voiding, however, the bladder neck and posterior urethra are normally widely patent and are often hydrodistended, as shown in Fig. 51.1. Wide patency of the posterior urethra confirms the absence of bladder neck and membranous urethral stenosis. Patients with anterior strictures in the absence of pelvic fracture

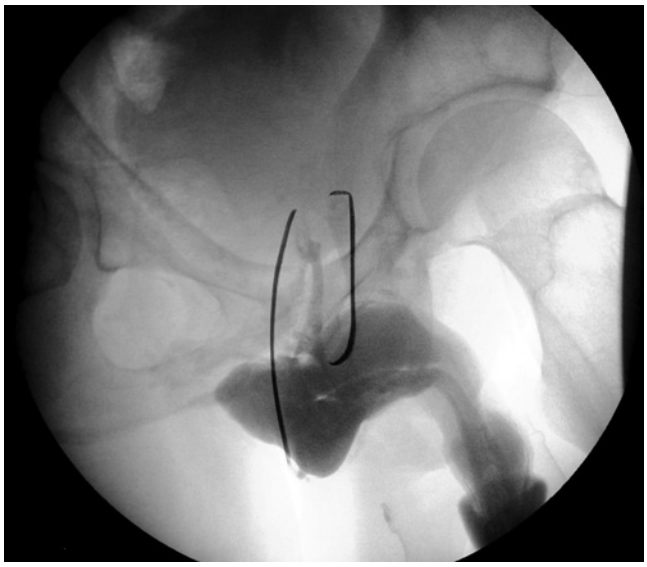


Figure 51.7 Outside retrograde urethrography obtained during a forceful attempt to advance the catheter for the injection procedure. The prostatic urethra and bladder neck cannot be assessed.

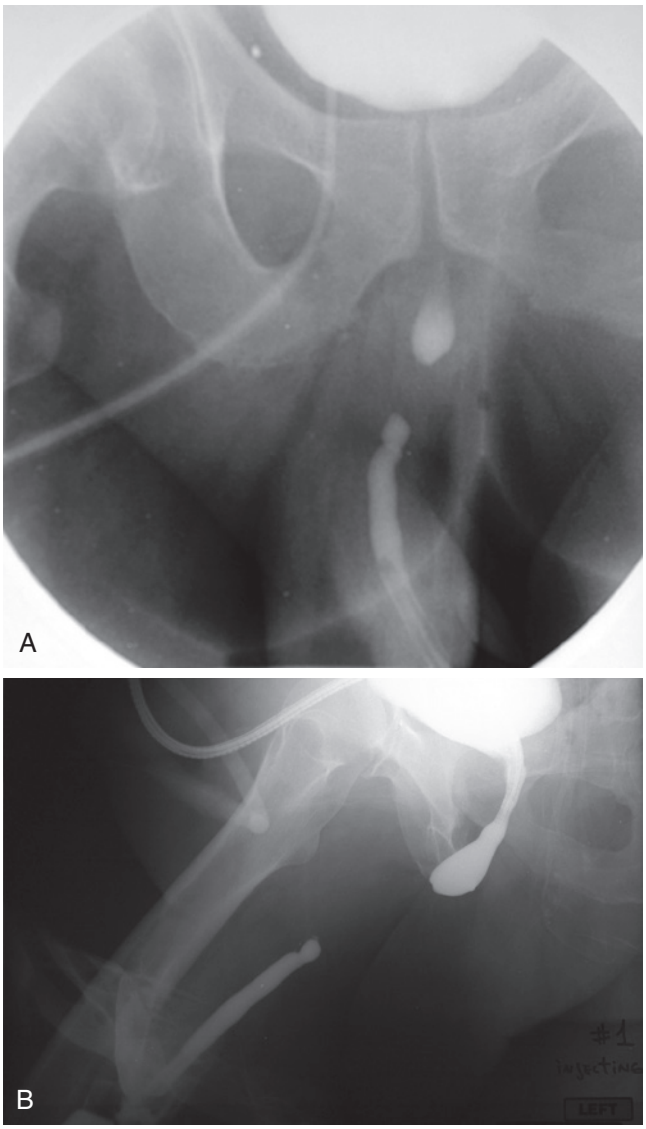


Figure 51.8 A, Contrast imaging with the patient in the supine position suggests a 2-cm obliteration. B, Repeat study with the same patient appropriately placed in the oblique position confirms that the obliteration is actually 8 cm in length.

trauma or prior prostate surgical or radiation therapy rarely have disease proximal to departure of the bulbar urethra. However, patients with bulbar strictures can also have membranous strictures, particularly when there has been prior endoscopic treatment. When VCUG is not performed, one possible consequence of incomplete imaging is an error in diagnosis that can compromise treatment outcomes.

Complications of Urethral Dilation

Urethral dilation is commonly used to manage urethral strictures. Dilation techniques include the use of metal sounds, filiforms and followers, catheters, and high-pressure balloons. Ideally, dilation should be performed in the absence of urinary tract infection or colonization. Intraoperative complications include the creation of a false passage, bleeding, urethral perforation, rectal injury, and failure to achieve the intended increase in urethral caliber. Balloon dilation with direct visualization was designed to minimize the risk of these severe complications.[3] Early postoperative complications include sepsis and urinary retention.

Urethral perforation, generally associated with significant bleeding, can be managed with gentle attempts at insertion of an indwelling catheter. The use of a flexible cystoscope to insert a flexible guidewire may facilitate the placement of a Council-tipped catheter. Suprapubic tube placement is a very reasonable option when a catheter cannot be placed without further trauma.

The most frequent long-term complication of urethral dilation is stricture recurrence, and recurrent strictures after multiple dilations may be longer and denser. Ideally, dilation is meant to only stretch the scar tissue, but in reality it tears open the strictured area, as evidenced by even minor urethral bleeding after the procedure. This tear then heals with more scar tissue, which can be more extensive than prior to treatment. Dilation represents a potentially curative treatment, although only for very discreet strictures with minimal associated spongiofibrosis.[4] Urethral squamous cell cancer is rare. However, chronic irritation from frequent dilations and self-catheterization is associated with an increased risk of developing this malignant disease. In patients with a history of chronic irritation who develop a fistula to the scrotum, priapism, or a very unusual appearance of the urethral mucosa seen on urethroscopy or contrast imaging, squamous cancer should be suspected.

Complications of Internal Urethrotomy

The Otis urethrotome was routinely used to incise urethral strictures blindly before the development of endoscopic

equipment that permitted direct vision internal urethrotomy (DVIU) with the use of a cold knife or a laser fiber. Incision of the scar into the corpus spongiosum increases the caliber of the urethra, and generally a catheter is subsequently placed. As with dilation, immediate complications can include bleeding, which is generally managed with catheterization and is usually self-limited, and damage to the urethra, which prevents subsequent catheter placement. Suprapubic tube placement is then indicated. Extravasation of blood or irrigation fluid into the scrotum or penis can occur and generally resolves with conservative management. However, extravasation into the periurethral tissues can significantly complicate dissection and mobilization of the urethra if subsequent open repair is required. Early complications include urinary tract infection and sepsis.

The most common complication is stricture recurrence. Along the circumference of the urethra epithelium is present, except where the urethra was incised. As healing occurs, the outcome is favorable when epithelialization results and leads to a stable increase in the caliber of the urethra. However, more commonly, wound contracture dominates, and the stricture recurs.

The actual recurrence rate after DVIU is not clearly defined in the literature because the multiple reports published on the subject do not include long-term objective follow-up. However, it is known and clearly established that long-term cure with urethrotomy is a reasonable expectation only for strictures that are not recurrent, are <1–1.5 cm long, and have minimal associated spongiofibrosis.[4,5] The recurrence rate with repeated urethrotomies is extremely high, and the standard of care for the initial management of longer strictures or of strictures that recur after incision is open reconstruction.[6,7] Investigators have reported that in patients who require open reconstruction after multiple failed DVIUs, the success rate is lower than when open surgical procedures are performed for initial management.[8,9]

Both DVIU and dilation have been reported to increase the risk of recurrence after urethroplasty, perhaps by worsening the degree of spongiofibrosis or lengthening of the stricture.[10,11] We have not found prior dilation or DVIU to compromise urethroplasty outcomes in our own experience, but we have observed strictures lengthen after endoscopic treatment, which may then require tissue transfer reconstruction when the original stricture would have been amenable to an excision and primary anastomosis.

Other complications of DVIU include erectile dysfunction that may be veno-occlusive because a deep dorsal urethral incision can extend into the corpus cavernosum and create a vascular shunt.[12] This complication was reported to be successfully treated with open urethral mobilization and fat pad interposition.[13] The overall rate of erectile dysfunction was 5.3% in one meta-analysis.[14] High-flow priapism following DVIU has also been reported and can be successfully treated with embolization.[15] Multiple incisions other than at the 12-o'clock position may reduce the incidence of this complication. Incontinence is generally not a complication of urethrotomy unless incisions involve the membranous urethra when the bladder neck is already compromised (e.g., after radical prostatectomy) or when the bladder neck is incised in patients whose membranous urethra is not fully intact.

Complications of Endoscopic Treatment of Posterior Urethral Injuries

In men who suffer pelvic fracture trauma and associated membranous posterior urethral disruption, immediate treatment options include a gentle attempt at catheter placement when a partial tear is diagnosed on RUG and suprapubic tube placement with delayed reconstruction. Immediate open urethral reconstruction is not indicated except when the injury is at the level of the bladder neck.[16]

Early primary realignment is a procedure that can be performed immediately in a stable patient or within the first week after the injury when the patient is stabilized. The technique involves endoscopic antegrade and retrograde urethral instrumentation in an effort to place a urethral catheter. As the pelvic hematoma is reabsorbed and healing occurs, the hope is that the catheter will guide the urethra back together in proper alignment, and the patient can then avoid the need for subsequent urethral reconstruction. If a stricture develops after catheter removal, the goals are for the realignment to reduce the length of the stricture or any misalignment and thus to facilitate subsequent repair. The success rate of primary realignment is not clearly established, although this technique is reported to be of possible benefit.[17–19] At this time, it is considered very reasonable to manage posterior urethral disruptions acutely with primary realignment or suprapubic tube placement and delayed reconstruction.

The most common complication of primary realignment is the development of a urethral stricture or total obliteration of the urethra after urethral catheter removal. One significant drawback of primary realignment is that recurrent strictures are then often managed with DVIUs and self-catheterization in an effort to avoid open reconstruction, subjecting the patient to multiple procedures and significantly delaying the time to resolution of stenosis.[20] When a recurrent stricture develops subsequent to urethral catheter removal, delayed open posterior urethral reconstruction is the standard of care and is generally performed approximately 3 months after urethral catheter removal.

In the past an endoscopic alternative to delayed open reconstruction for obliterative distraction defects was a "cut-to-the-light" procedure. This technique involved simultaneous antegrade and retrograde cystoscopy with "core through" incisions into the obliteration toward the light of the other scope until continuity was established. The failure rate was very high, and this technique fell out of favor and is not recommended.

Complications of Urethral Stents

The UroLume stent (American Medical Systems, Minnetonka, MN) was taken off the market as of January 2013 and is no longer manufactured, but patients who have had these placed may still suffer from future complications. Complications that have occurred with high frequency include pain, infection, incontinence, and recurrent strictures within the stent or proximal or distal to the stent.[21] Development of a panurethral stricture can also occur in

patients with hypospadias.[22] Recurrent strictures that develop after stent placement can be successfully managed with open stent removal using excision and primary anastomosis for relatively short proximal strictures or with tissue transfer reconstruction for longer strictures. Individualized open reconstruction can generally be performed in one stage and has a high long-term success rate.[23]

Complications of Open Surgical Procedures

Open surgical procedures for urethral reconstruction include excision and primary anastomosis and tissue transfer reconstruction with skin flaps or grafts. The remainder of this chapter is a discussion of complications associated with patient positioning, excisional repair for posterior and anterior bulbar strictures, graft harvest, and tissue transfer reconstruction.

PATIENT POSITIONING

Distal strictures involving the urethral meatus, fossa navicularis, and penile urethra are often repaired with the patient in the supine position. If care is taken to prevent pressure points, positioning complications generally do not occur. In contrast, more proximal strictures are repaired by a perineal approach that requires placement of the patient in the lithotomy position, often an exaggerated lithotomy position (Fig. 51.9). This position is associated with many complications including neuropraxia (peroneal nerve in particular) that is often temporary but can be permanent, back pain, compartment syndrome, and rhabdomyolysis.[24–26]

Proper positioning can reduce the incidence of these serious complications. A modified Skytron table (developed by Gerald Jordan, MD) provides pelvic tilt, and modified stirrups allow additional extension of the lower extremities to prevent extreme hip or knee flexion with associated nerve stretch. Proper adjustment of the boots of the stirrups prevents pressure on the calves and reduces the risk of compartment syndrome, a condition that when diagnosed is generally managed with emergency fasciotomies. Investigators have shown that the time spent in the lithotomy position is related to the risk of the development of compartment syndrome, neuropraxia, and rhabdomyolysis.[27, 28] Therefore, when possible, any portion of the surgical procedure (e.g., buccal graft harvesting when indicated) that can be done without the patient being in the exaggerated lithotomy position should be done with the patient supine. This can be facilitated by obtaining proper imaging preoperatively, which allows the surgeon to accurately determine how much buccal graft is needed, if any, prior to positioning in lithotomy. When neuropraxia develops, it is usually a temporary sensory impairment along the lower leg and the dorsum of the foot in particular. One report of 185 patients found 12 patients with neuropraxia, which was by far the most common positioning-related complication, but only one of these was severe.[24] Normal sensation usually returns without treatment in 2 to 3 days. However, more significant and long-term disability can occur along with motor deficits, including but not limited to impaired dorsiflexion of the foot.



Figure 51.9 Exaggerated lithotomy position.

Rhabdomyolysis is a potentially serious complication of prolonged lithotomy positioning with associated painful muscle damage. The serum creatine kinase level is markedly elevated, and myoglobin may be detected in the dark brown urine. Acute renal failure with oliguria and elevation of the serum creatinine may occur. Aggressive treatment is indicated to prevent renal damage, and appropriate management includes hydration and urine alkalization. Temporary dialysis is required in severe cases. In addition, deep vein thrombosis and pulmonary embolism have been reported as possible complications of high lithotomy positioning, although a large population-based study of 126,891 patients undergoing urologic surgery actually found that the lithotomy position conferred a lower risk of these complications than did the supine position.[29]

SUPRAPUBIC TUBE PLACEMENT

Suprapubic tubes are critical for the initial management of pelvic fractures associated with urethral injuries and are also routinely placed at the time of anterior urethral reconstruction at some centers. Potential benefits include the ability to use a smaller stenting urethral catheter yet maintain adequate bladder drainage postoperatively and the establishment of a secondary source of bladder drainage should one tube become plugged. Potential complications include bleeding and posterior bladder injury. The most serious complication of percutaneous suprapubic tube placement is bowel injury. During suprapubic tube placement, it is important that the bladder be distended, and this can be achieved through slow retrograde filling with saline solution through a flexible cystoscope with the tip of the scope distal to the stricture. The tube should be inserted no more than 2 to 3 cm cephalad to the midline pubic symphysis, and open tube placement or ultrasound guidance should be considered in patients who have a history of prior lower abdominal or pelvic surgery.

EXCISION AND PRIMARY ANASTOMOSIS FOR POSTERIOR DISRUPTIONS

The most common complication of posterior urethral reconstruction with excision and primary anastomosis is recurrence of the stricture or obliteration. Technical success is defined as durable wide patency of the entire urethra without the need for any subsequent or other intervention. At referral centers for urethral surgery, the success rate of posterior urethral reconstruction (including both initial treatment and revision) is 90–98%.[30,31] Factors that increase the probability of a technically successful outcome include the administration of culture-specific antibiotics perioperatively, complete scar excision so the proximal and distal segments of the urethra are widely spatulated to >30Fr with healthy mucosa circumferentially, and a tension-free repair.[32]

Maneuvers that promote a tension-free repair include midline separation of the corporal bodies along the triangular ligament and, when indicated, infrapubectomy. In rare cases, corporal rerouting has been reported to reduce tension. Investigators have stressed in the literature that posterior reconstructions and urethral reconstructions in general are best performed by urologists with expertise and specialization in urethral stricture surgery because a poor outcome increases the complexity and difficulty of subsequent surgical treatment.

Long recurrent total obliterations that develop as early complications of failed surgical procedures (Fig. 51.10) are likely caused by inadequate proximal exposure and scar excision. Fortunately, these patients can usually undergo corrective treatment with a very high success rate with repeat excisional repair.[33] The finding that revision surgery was highly successful with the same operation that previously failed before referral suggests that the experience of the surgeon may be significantly related to the success of the operation. Discrete nonobliterative anastomotic recurrences can be successfully managed with urethrotomy. In contrast to the low success rate of DVIU for the initial treatment of strictures, this technique has a high success rate when it is used to treat anastomotic strictures, presumably because these discrete recurrent strictures are not associated with any significant spongiofibrosis.[34]



Figure 51.10 Urethral imaging in a patient who previously underwent a technically unsuccessful posterior urethral reconstruction.

A potential complication of posterior urethral reconstruction is ischemic stenosis of the anterior urethra.[35] The anterior urethra has a dual blood supply. The bulbar arteries provide antegrade supply to the anterior urethra within the corpus spongiosum. In addition, the dorsal arteries supply the glans penis and the anterior urethra in retrograde fashion. Posterior urethral reconstruction cannot be performed without compromising the bulbar arteries at the time of urethral transection. Therefore, the anterior urethra is subsequently supplied predominantly by the dorsal arteries. If this blood supply is bilaterally compromised by arterial injury, ischemic stenosis can develop as a complication of posterior urethral reconstruction.[36]

Vascular evaluation enables the surgeon to identify patients who may be at risk of developing this complication. Patients with normal erectile function invariably have adequate urethral vascularity. A penile duplex study with pharmacologic erection in patients with postinjury erectile dysfunction identifies patients with bilateral arterial inflow compromise. Patients with severe inflow impairment should then undergo a pudendal arteriogram, and when bilateral dorsal artery compromise is evident, penile revascularization (generally inferior epigastric to dorsal artery) should be performed before urethral reconstruction. One study reported successful urethroplasty in all patients with bilateral complete obstruction of the deep internal pudendal arteries who underwent revascularization.[37]

In men who sustain pelvic fracture trauma and associated urethral disruption, erectile dysfunction from nerve or vascular injury is not uncommon.[35] Although erectile dysfunction is a possible complication of posterior urethral reconstruction, impotence is usually secondary to the initial injury. Given that urethral reconstruction generally cures the urethral stricture but does not address the associated erectile dysfunction caused by the initial injury, the most common long-term urologic problem is erectile dysfunction. A recent meta-analysis found de novo erectile dysfunction present in 34% of patients after a pelvic fracture urethral injury *before* urethroplasty, with only an additional 3% reporting de novo erectile dysfunction after definitive urethroplasty.[38]

Incontinence is also a possible complication of urethral reconstruction. However, when this complication occurs, it is generally at least in part related to the initial injury. The typical location of the urethral injury following pelvic fracture trauma is the membranous urethra. Surgical reconstruction of the urethra does not involve dissection proximal to the apex of the prostate, and the dissection is definitely distal to the bladder neck. When the membranous urethra is damaged but the bladder neck is intact, the ability to stop voiding voluntarily is affected, but continence is generally preserved. Incontinence after posterior urethral reconstruction, when present, is therefore related to associated bladder, nerve, or bladder neck damage and not the reconstructive surgical procedure, on the assumption that the anastomosis is made at the most distal area of the patent proximal segment distal to the verumontanum of the prostate. Urodynamic evaluation is recommended if incontinence occurs after urethral reconstruction.

Other potential complications include bleeding, although transfusion should be very rarely indicated. Wound infection is always a potential complication of open urethral

surgical procedures. Superficial wound infections should be promptly recognized and managed with incision and drainage if fluctuance is noted. Antibiotics are effective treatment for cellulitis.

EXCISION AND PRIMARY ANASTOMOSIS FOR PROXIMAL ANTERIOR STRICTURES

Stricture excision and primary anastomosis have long been the open procedures of choice for relatively short strictures of the bulbar urethra. When the surgical procedures are properly performed at a referral center for urethral reconstruction, the success rate is reported as high as 98.8%.[39] Strictures 1–2 cm long are highly amenable to excisional repair, whereas lengthier excisions may lead to penile shortening or ventral curvature with erection. However, longer bulbar strictures can be managed with primary repair without the development of chordee in selected patients with adequate elasticity of the corpus spongiosum located within the proximal bulbar area.[40]

Anterior urethroplasty with excisional repair shares many of the complications noted with posterior repair including recurrence, positioning complications, bleeding and infection, and chordee. Other sexual complications that have been reported include ejaculatory dysfunction and change in glans fullness or sensation.[41] It is important to note that we have not found these complications to be common or unique to this technique in our own experience. Fistula and diverticula formation are not at all commonly seen with excisional repair because the corpus spongiosum is present circumferentially to provide support and to prevent diverticular change, and the perineal skin is separated from the urethral lumen by subcutaneous fat, the bulbospongiosus muscle (especially along the mid-proximal bulbar urethra), and the corpus spongiosum, which is most prominent along the ventral aspect of the urethra.

GRAFT HARVEST

When tissue transfer with grafting is required for urethral reconstruction, the most commonly used graft material currently is buccal mucosa. Grafts are usually harvested from the lateral cheeks, although the lower lip and tongue can be used and, occasionally, the upper lip can be a source of additional graft material.[42–44] Short-term speech impairment and dysgeusia can be encountered after lingual grafts, while deformity and tightness are greater concerns when grafts are harvested from the lower and especially the upper lip, and therefore it is preferable to harvest grafts from the lateral cheeks. When a lateral buccal graft is harvested, Stensen's duct is identified adjacent to the second upper molar, and the area for graft harvest is then incised inferior to the opening of the duct (Fig. 51.11).

Injury to Stensen's duct is a possible complication of buccal graft harvesting, but it can usually be avoided by proper identification of the duct. The morbidity associated with buccal mucosa graft harvest was previously reported.[45] In this report, most patients experienced significant postoperative pain that was worse than expected. Postoperative side effects included periorbital numbness that persisted for >6 months in 9% of the patients, initial difficulty with mouth opening, and changes in salivation. One patient developed a mucus retention cyst that required excision. Some surgeons close the donor site, and others leave the harvest site open. Recently, however, a randomized controlled trial of 50 patients showed that those patients whose donor site was left unclosed reported lower early pain scores, an earlier return to a full diet, an earlier return to full mouth opening, and a decrease in bothersome perioral numbness at 6 months postoperatively.[46]

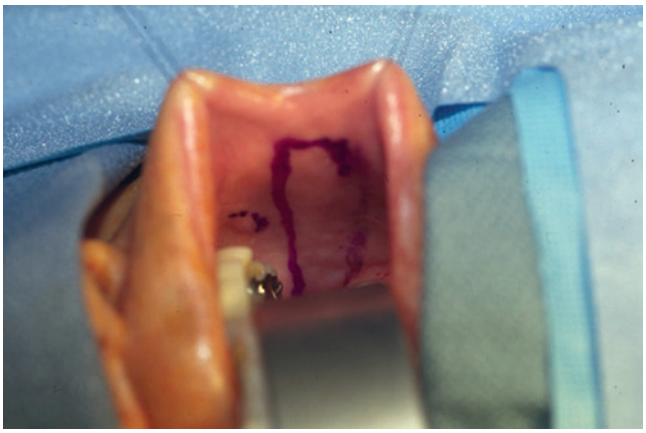


Figure 51.11 Buccal mucosa is marked for harvest, and Stensen's duct is identified.

In addition to buccal grafts, other autologous graft materials used in urethral reconstruction are split-thickness skin grafts (STSG), often harvested from the thigh and temporalis fascia. The harvest of any graft can be associated with bleeding, scarring, contracture (generally not with split-thickness grafts), and infection. However, these grafts can generally be harvested with low morbidity.

TISSUE TRANSFER RECONSTRUCTION

All tissue transfer reconstructions, and stricture repairs in general, can be complicated by stricture recurrence, urethrocutaneous fistula, post-void dribbling, and sexual dysfunction.

Significant incontinence of urine from the bladder is generally not a complication of anterior urethral reconstruction because the surgical procedure is performed distal to both the bladder neck and the external urethral sphincter. However, after tissue transfer reconstruction in particular, the urethra does not coapt normally, and pooled urine present within the reconstructed segment of the urethra after voiding can dribble out after urination.[47] This phenomenon may be worse in patients who have had a ventral onlay repair, as the graft bed is less robust than if placed dorsally against the corporal bodies.[48] Patients who report this complication should be instructed to "milk" their urethra with their hand from behind the scrotum toward the urethral meatus after urination.

Sexual dysfunction can occur after anterior urethral reconstruction, but one study revealed that the incidence of erectile dysfunction was no higher after urethroplasty than after circumcision.[49] However, another study reported that patient satisfaction with the outcome of urethroplasty was related not only to relief of obstructive symptoms but

also to an absence of chordee or tethering.[50] When penile skin is repeatedly used to repair recurrent strictures after failed hypospadias repair, and subsequent salvage procedures fail, patients are at risk for significant compromise of sexual function (Fig. 51.12). It is important not to compromise the stretched and erect penile length significantly during repeat urethral reconstruction and not to proceed with tubularization during a staged repair if any chordee has not been fully addressed.

Additional complications may include bleeding, urinary tract infection with or without sepsis, and wound infection, and breakdown of the repair also may occur. However, specific complications are generally associated with flap and graft reconstructions.

FLAP RECONSTRUCTION

Skin flaps by definition retain their blood supply because they are mobilized on a vascular pedicle and are relocated to augment the caliber of the urethra. The most commonly used flap is a penile skin flap. The penile skin is supplied by branches of the superficial external pudendal arteries. These vessels course along the tissue deep to the skin and superficial to Buck's fascia. The supply is axial as opposed to random and is defined. During the elevation of a penile skin flap, under optical magnification, a tissue plane is developed between the superficial and deep plexus of the fascia. Careful attention to technical detail is required so that blood supply is maintained both to the skin flap and to the remaining penile skin.

Potential complications of flap elevation include ischemic changes to the penile skin, especially along the distal aspect, and flap ischemia.[51] Penile skin sloughing was reported in 4% of patients undergoing a penile circular fasciocutaneous skin flap, and 3% developed a urethrocutaneous fistula.[52] Distal penile skin ischemia and necrosis are generally managed with debridement of devitalized tissue and wound care. In general, the skin is adequately redundant so that the loss of a small amount of penile skin is not disabling. In patients who previously underwent flap repair and who develop a recurrent stricture, a penile flap may be elevated again by some surgeons. However, once a flap is used, the blood supply of the penile skin is not axial and well defined, but rather random in distribution. Therefore repeated use of skin flaps can be associated with a higher rate of ischemic flap failure and recurrent stricture formation.

Although currently not commonly used as a urethral replacement, scrotal skin can be used for urethral reconstruction. When scrotal skin is rotated as a flap, it must be nonhirsute. In addition, the skin must be marked on stretch to avoid redundancy that can be associated with diverticula formation (Fig. 51.13). Penile skin flaps must also be nonhirsute. In general, the foreskin and distal penile shaft skin are not hair bearing. However, before shaving and draping, when skin flaps are to be used, the skin should be evaluated under optical magnification to ensure that only nonhirsute skin is selected. When hair-bearing skin is used to repair the urethra, hair will then grow within the lumen of the reconstructed urethra (Fig. 51.14) and may be a source of infection, stone formation, or recurrent obstruction[53].

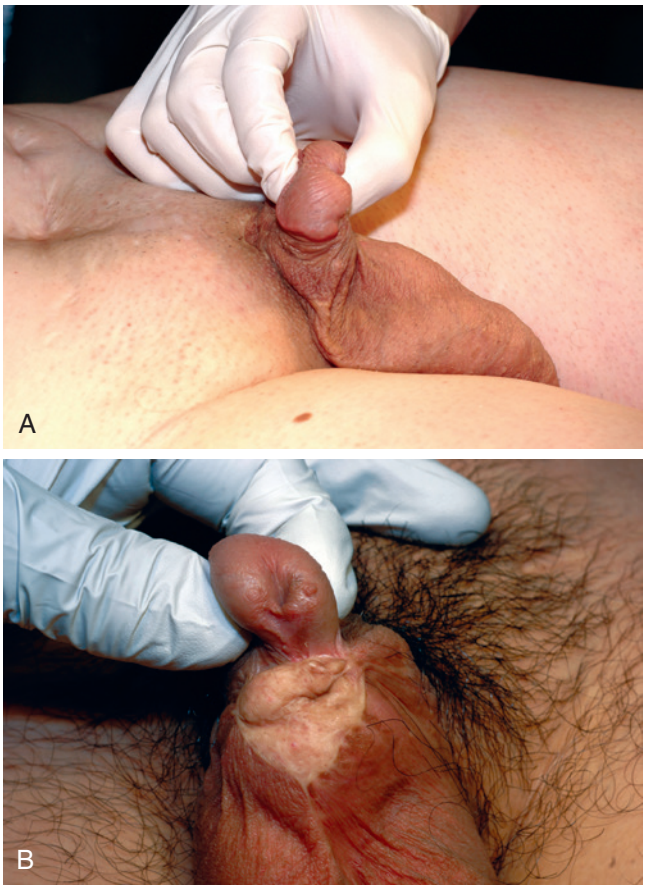


Figure 51.12 A and B, These two patients previously underwent multiple failed hypospadias repair procedures. The stretched penile length, as shown, is <2 inches.

GRAFT RECONSTRUCTION

Grafts are detached from their blood supply at the donor site and are transferred to a recipient bed. Grafts obtain blood supply through a process of graft take. Initially, the graft receives nutrients by passive diffusion, a process called imbibition. Then, neovascularization occurs. This is called inosculation. One possible complication is failure of the graft to take. Proper surgical technique significantly reduces the likelihood of graft-take failure. The graft must be firmly approximated to the recipient bed. This is facilitated by creating small slits within the graft to allow blood to escape that may elevate the graft from the recipient bed and prevent neovascularization. In addition, grafts are now often quilted to the recipient bed by using multiple fine absorbable sutures to provide further fixation because graft movement during the process of imbibition and inosculation is deleterious to graft take.

Buccal grafts can be used for one-stage reconstructions as a dorsal, ventral, or lateral onlay or for staged repairs. STSGs are generally only used for staged repairs when there is not enough oral mucosa. Buccal mucosa is a better graft material than is STSG because success rates are higher with buccal grafts than with skin grafts, and chordee occurs less, given that skin is much less elastic than is buccal mucosa.[50] However, the supply of buccal mucosa is limited.

As with other techniques of urethral reconstruction, stricture recurrence is the main complication with graft

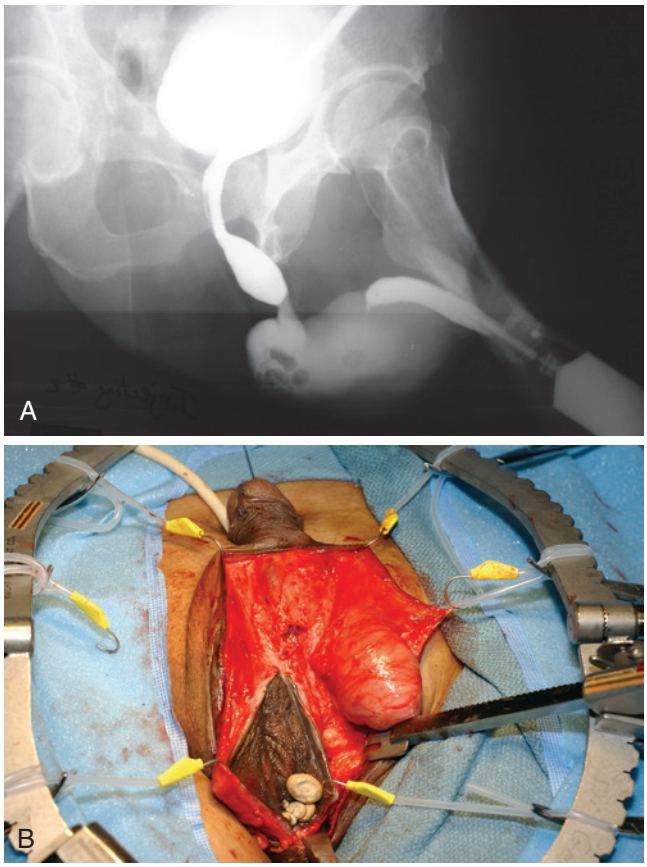


Figure 51.13 A, Retrograde urethrography demonstrates a markedly dilated proximal penile and distal bulbar urethral diverticulum that contains filling defects in a patient who previously underwent a one-stage tubed tissue transfer repair with scrotal skin. B, At the time of surgery, the massive diverticulum contained multiple stones.

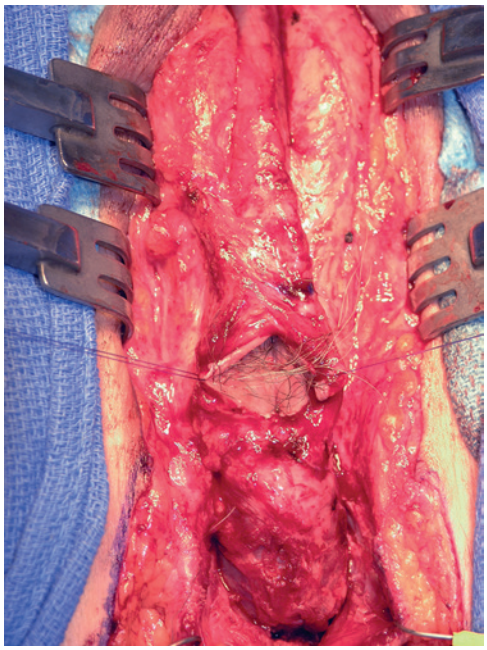


Figure 51.14 Hair developed within the lumen of the urethra after reconstruction using hair-bearing genital skin.

repairs. In addition to attention to surgical detail, procedure selection is a factor that influences the success rate. In general, the success rate is higher when transferred tissues are used for onlay repair than for tubed reconstruction.[54] In comparison with STSGs and penile skin flaps, buccal grafts appear to have a higher success rate.[55] The results with onlay buccal mucosa grafts are excellent regardless of whether the graft is placed dorsally and is quilted to the corporal bodies, as originally described by Barbagli and associates,[48] or is placed ventrally or laterally.[56]

Urethral stricture disease associated with LS was previously commonly managed with penile skin flap repair. However, investigators showed that, although short-term success rates with flap procedures were high, the long-term failure rate 10 years postoperatively was extremely high.[57] As a result, the shift in management has been toward staged repairs using extragenital tissues.[58] LS is a frustrating disease that can recur and lead to stricture recurrence even after technically successful staged repairs. Extended meatotomy or proximal urethrostomy has been proposed for complex cases as the most appropriate surgical treatment.[2]

Diverticula formation and the development of urethrocutaneous fistulas are rarely seen when buccal mucosa is used for urethral reconstruction in patients without hypospadias because the urethra is circumferentially well supported and the penile skin is separated from the urethral lumen by the corpus spongiosum. However, when staged repairs and skin flaps are performed, particularly in patients with *hypospadias*, which is a condition associated with a poorly developed distal corpus spongiosum, urethrocutaneous fistula is a more common complication.[59] These fistulas, when persistent, can be closed primarily but may then recur. Recurrent fistulas may require more complex closure with the interposition of a tunica vaginalis flap.

Conclusions

Urethral reconstruction, when properly performed using modern techniques, is generally associated with a high long-term success rate and a low complication rate. For all repairs, recurrence is the most common complication. Many published reports include follow-up with urethroscopy or contrast imaging 3–12 months after treatment to assess the short-term outcome. This testing is less frequently done after urethrotomy or dilation but is certainly not less indicated given the higher stricture recurrence rate with endoscopic treatment than with open treatment. A low early recurrence rate suggests technical success. However, long-term follow-up reveals that even when short-term success is objectively confirmed, a stricture may recur 5–10 or more years after the surgical procedure. This is especially true in patients with LS and after substitution urethroplasty.[60] Therefore indefinite periodic follow-up is recommended because the previously mentioned complications of stricture observation are also the possible complications of unrecognized and untreated recurrence.

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Chapter 51 Questions

1. Which of the following is not a complication of observation as a management strategy for a significant urethral stricture?
   a. Recurrent epididymitis
   b. Penile curvature
   c. Urinary tract infections
   d. Bladder decompensation
   e. Poor quality of life

2. What is the ideal technique when performing a retrograde urethrogram?
   a. Patient in oblique position, injection of contrast through a catheter with 1 mL in the balloon
   b. Patient in supine position, injection of contrast through a catheter with 1 mL in the balloon
   c. Patient in oblique position, injection of contrast through a coned tip adaptor
   d. Patient in supine position, injection of contrast through a coned tip adaptor
   e. Patient in oblique position, injection of contrast through a catheter with 2 mL in the balloon

3. What is the best imaging test to assess for stenosis of the posterior urethra?
   a. Retrograde urethrogram
   b. Voiding cystourethrogram
   c. Ultrasound
   d. MR-urogram
   e. CT-urogram

4. What is the most common complication from repeat urethral dilation and direct internal visual urethrotomy?
   a. Bleeding requiring transfusion
   b. Urinary tract infection
   c. Creation of a false passage in the urethra
   d. Positioning-related complications
   e. Stricture recurrence

5. The main blood supply to a penile skin flap is derived from:
   a. Common penile arteries
   b. Internal pudendal arteries
   c. Superficial external pudendal arteries
   d. Circumflex arteries of the penis
   e. Neovascularity after the tissue "takes"

6. What is the most common positioning-related complication that results from the extended lithotomy position?
   a. Transient neuropraxia
   b. Impaired gait
   c. Acute renal failure from rhabdomyolosis
   d. Stress fracture in the lower extremity
   e. Compartment syndrome

7. A patient with which of the following histories should have an abdominal ultrasound performed at the time of placement of a suprapubic catheter?
   a. Hypospadias
   b. Prior suprapubic tube placement
   c. Prior repair with penile skin flap
   d. Prior ureteral reimplant
   e. Panurethral stricture

8. Erectile dysfunction following an excision and primary anastomosis for a urethral distraction injury related to pelvic fracture is most likely due to:
   a. The initial injury
   b. Failed attempts at early endoscopic primary realignment
   c. Early suprapubic tube placement
   d. The definitive repair with excision and primary anastomosis
   e. Persistent bacteriuria associated with indwelling catheters

9. A complication that appears to be unique to the harvesting of a lingual graft is:
   a. Postoperative pain
   b. Short-term difficulty eating solid foods
   c. Contracture of the graft site
   d. Difficulties with speech
   e. Worse bleeding complications

10. Leakage of a small amount of urine after voiding is most likely seen after which of the following procedures?
    a. Urethral dilation
    b. Direct vision internal urethrotomy
    c. Excision and primary anastomosis
    d. Ventral onlay flap
    e. Dorsal onlay graft

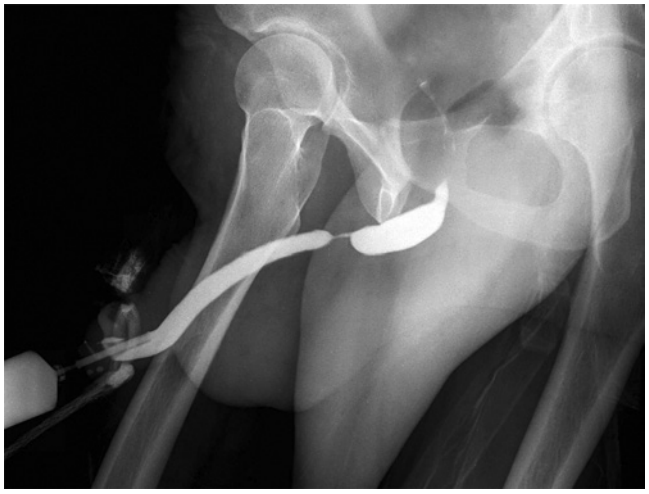
Case Studies

CASE 1

A 27-year-old man with no significant history presents with progressive weakening of his stream over the past year. His physical exam is unremarkable but his peak flow is diminished on a flow study. During the course of the work-up, cystoscopy is performed that reveals a stricture in the bulbar urethra.

1. While you are visualizing the distal aspect of the stricture, what is the appropriate next step?
   a. Advance the cystoscope through the stricture with gentle dilation if necessary, to determine the length and visualize the bladder
   b. Terminate the cystoscopy and schedule for an endoscopic internal urethrotomy
   c. Terminate the cystoscopy and perform a retrograde urethrogram
   d. Terminate the cystoscopy and schedule for a suprapubic tube placement
   e. Terminate the cystoscopy and schedule for a urethral reconstruction

2. Retrograde urethrogram is shown in Case Fig. 51.1. Which management option is likely to have the highest success rate?
   a. Urethral dilation
   b. Direct vision internal urethrotomy
   c. Excision and primary anastomosis



Case Figure 51.1

d. Dorsal buccal onlay urethroplasty
e. Ventral onlay penile skin flap

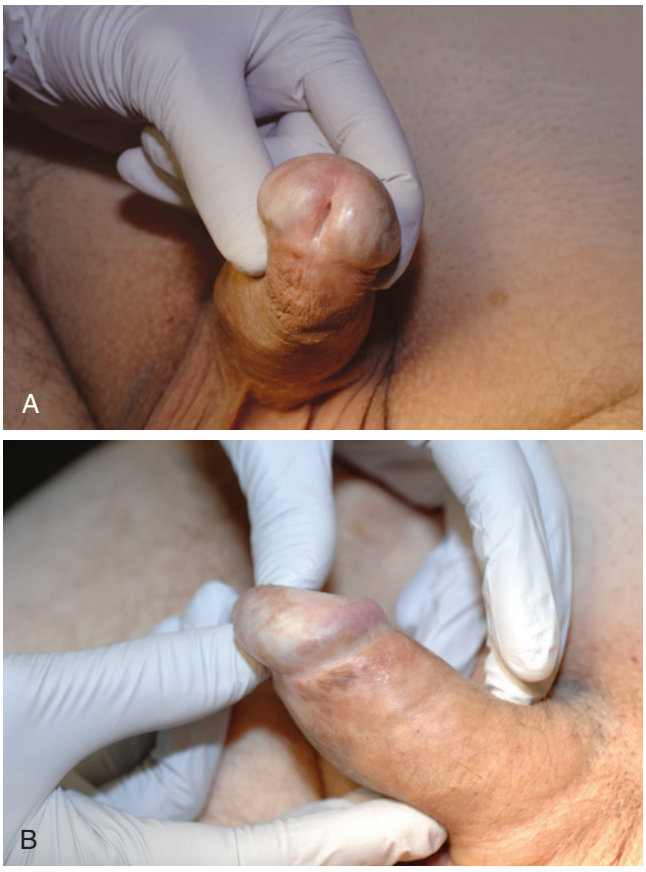
3. What can be done during the procedure to minimize positioning-related complications?
   a. Minimize the time in exaggerated lithotomy
   b. Ensure hips are flexed as much as possible
   c. Ensure knees are flexed as much as possible
   d. Avoid the use of a retractor
   e Ensure the elbows are fully extended

CASE 2

A 53-year-old man presents with a long history of a distal stricture. His previous urologist has dilated him many times in the past. He was most recently dilated 3 weeks ago, but his obstructive symptoms have already returned. His physical exam reveals meatal stenosis with a whitish discoloration of the glans and distal penile shaft skin as seen in Case Fig. 51.2.

1. What is his likely underlying diagnosis?
   a. Prior trauma
   b. Urethritis secondary to a sexually transmitted infection
   c. Lichen sclerosis, otherwise known as balanitis xerotica obliterans (BXO)
   d. Paget's disease
   e. Idiopathic meatal stenosis

2. The patient desires definitive intervention, but tells you his flow is worsening rapidly and may go into retention in the next few days to weeks. You check a post-void residual and it is 350 mL. What is the appropriate next step?
   a. Schedule for urethroplasty within the next few days
   b. Place a suprapubic tube and delay his definitive work-up and repair for another 2–3 months
   c. Dilate him in the office so that an immediate workup with cystoscopy and retrograde urethrogram can be performed



Case Figure 51.2

   d. Place him on self-dilation until a definitive repair can be scheduled
   e. Place him on a topical steroid until definitive repair can be scheduled

3. After placement of a suprapubic tube, a retrograde urethrogram 3 months later reveals a 5-cm stricture involving the fossa navicularis and most of the penile urethra. Which of the following options is most likely to fail?
   a. Extended meatotomy
   b. Perineal urethrotomy
   c. Staged procedure with buccal grafting
   d. One-stage urethroplasty with penile skin flap
   e. All of the above have excellent long-term success

Answers

1. **b.** High-pressure backflow in the urethra may cause reflux into the prostatic ducts leading to prostatitis or epididymitis. Bladder diverticula, poor emptying, and urinary tract infections may also arise from high pressure voiding. There is no association of strictures with penile curvature.
2. **c.** Imaging performed while supine can severely underestimate the stricture length and therefore should be done in the oblique position. Even placing 1 mL creates a balloon that is 39Fr in caliber, which is far greater than a normal 24Fr fossa navicularis and may

therefore create a new stricture due to the trauma of such forceful dilation.

3. **b.** Posterior urethral stenoses are not readily appreciated because the bladder neck and external sphincter are both closed at rest. During a retrograde urethrogram, it is normal for the posterior urethra to be coapted and therefore a contracture or stenosis could not be distinguished. Voiding cystourethrogram is the only option that visualizes the posterior urethra while these structures are opened.
4. **e.** Long-term stricture recurrence rates for repeat dilations or urethrotomies is unacceptably high, and therefore these procedures are recommended only for short strictures that have not been previously treated.
5. **c.** The penile skin is supplied by branches of the superficial external pudendal arteries that course along the tissue deep to the skin and superficial to Buck's fascia. Unlike grafts, flaps are transferred with their blood supply intact and do not rely on "take."
6. **e.** Transient neuropraxia, particularly on the dorsum of the foot, is the most common positioning-related complication in the lithotomy position. This will typically resolve within days.
7. **d.** Patients with prior lower abdominal or pelvic surgery are at higher risk of having bowel in the path of the ideal suprapubic tract.
8. **a.** While performing a posterior urethroplasty carries some risk of de novo erectile dysfunction, the literature suggests that the large majority of these patients had ED since their initial injury. There is no evidence that the other options are correlated with erectile dysfunction in this scenario.
9. **d.** Difficulty with speech is often reported postoperatively after the harvesting of a lingual graft, while pain, short-term difficulty with solids, and contracture of the graft site can occur with buccal and lower lip grafts as well. There is no evidence that bleeding is worse with lingual grafts.
10. **d.** Post-void dribbling is common after any substitution urethroplasty because the substitute material does not coapt like normal urethra, leaving a small amount of urine within the repaired section. Ventral onlay repairs, either with a graft or a flap, are more likely to be associated with this issue than are dorsal repairs, which are fixated to the firm corporal bodies that supply more support than the ventral repairs.

CASE 1

1. **c.** Cystoscopy is not an adequate procedure to determine the length of a stricture. Therefore, it should be terminated and a retrograde urethrogram should be performed to determine the exact length and location as these factors are needed to determine the best treatment option.
2. **c.** The retrograde urethrogram shows an approximately 1 cm bulbar urethral stricture. In this case, excision and primary anastomosis has been shown to have the highest success rate.
3. **a.** Extended time in exaggerated lithotomy has been associated with positioning complications such as neuropraxia or even compartment syndrome, although the latter is rare.

CASE 2

1. **c.** The whitish discoloration of the glans and distal penile shaft as seen is classic for lichen sclerosis, it is typically not seen with the other options.
2. **b.** Given his recent dilation 3 weeks ago, the stricture is likely still maturing. If immediate intervention is taken, it will be difficult to tell how proximal the stricture disease truly extends. Placement of a suprapubic tube allows excellent bladder drainage while the stricture matures and then can be appropriately worked up 2–3 months later. A topical steroid may help prevent future recurrence, but would not cure his current stricture.
3. **d.** As lichen sclerosis is a cutaneous disease, use of a penile skin flap is contraindicated as recurrence is highly likely in this situation. The other 3 procedures mentioned have acceptable success rates.

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52 Complications of Surgery for Erectile Dysfunction and Peyronie's Disease

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CHAPTER OUTLINE

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KEY POINTS

1. Infection remains a significant concern, with rates between 1% and 8%.
2. In the setting of infection, device removal is highly recommended. Immediate reinsertion of the prosthesis is associated with long-term success in 45 of 55 patients in one study.
3. Despite the potential complications of the penile prosthesis, satisfaction rates remain high.
4. Peyronie's disease surgery should be undertaken in the properly selected patient with realistic expectations of the potential outcome.
5. Complications of Peyronie's procedures include hematoma formation, decreased penile sensation (anesthesia, dysesthesia), erectile dysfunction, bother from palpable suture material, penile skin necrosis, penile length loss, and recurvature.

Introduction

Surgical treatments for erectile dysfunction and Peyronie's disease are always elective procedures that a patient chooses to improve his quality of life. As a result, complications associated with any of these procedures are especially disappointing to the patient and disheartening for the surgeon. Communicating the possible complications of these surgeries is vital to ensuring that the patient is making a fully informed decision about whether to proceed with surgery. An extensive knowledge of the possible complications associated with these surgeries will also help the surgeon to prevent, as well as skillfully manage, these complications such that outcomes are optimized.

Penile Prosthesis Surgery

Penile prostheses are generally of two types: malleable (semirigid, noninflatable, nonhydraulic) and inflatable (hydraulic) devices. The malleable devices have an outer shell with a central core of metal or plastic. These prostheses are paired solid devices implanted in the corpora cavernosa that produce constant penile rigidity. The primary advantage of these devices is their ease of implantation, whereas the disadvantages include a constantly rigid penis that resembles neither normal erection nor flaccidity, difficulty with concealment, and an increased risk for device erosion.

Inflatable devices are of two varieties: two-piece and three-piece devices. Since its introduction in 1973, the inflatable penile prosthesis has undergone multiple changes in design and manufacturing. American Medical Systems (AMS, Boston Scientific, Marlborough, MA) produces both types of inflatable devices (Fig. 52.1). Coloplast (Minneapolis, MN) produces only three-piece devices (Fig. 52.2). Numerous modifications have been made to improve function and survival of the devices. Such modifications include, but are not limited to, a reservoir or pump lockout valve to prevent autoinflation, antibiotic or antiadherence



Figure 52.1 AMS 700 series three-piece inflatable implant.



Figure 52.2 Coloplast Titan series three-piece inflatable implant.



Figure 52.3 AMS Ambicor two-piece penile implant.

Box 52.1 Patient Populations to Consider a Two-piece Prosthesis

Has undergone, or is planning to undergo, a renal transplant
Has had a bilateral inguinal herniorrhaphy (especially with mesh)
History of spinal cord injury and uses condom catheter (solid distal 2 cm of cylinders support the condom catheter)
Certain patients who have undergone radical prostatectomy (it can be challenging to develop enough space to prevent autoinflation in 5–10% of men)
Older men whose manual dexterity makes using the three-piece deflation mechanism difficult to use

coating to reduce infection, Parylene (a polyxylylene polymer) coating for the AMS three-piece devices to improve cylinder longevity, and modifications of the scrotal pump to improve ease of use for the patient.

The AMS two-piece device (Ambicor) consists of two cylinders with the distal 2 cm made of solid silicone (Fig. 52.3). The cylinders are connected to a ball-shaped pump, which is seated within the scrotum. Compression of the pump results in transfer of fluid from the basal part of the cylinders into the middle portion, with subsequent rigidity. The deflation mechanism involves simple bending of the cylinders midshaft to return the fluid to the basal section. Three-piece inflatable implants have paired cylinders, a small scrotal pump, and a large-volume fluid reservoir. These devices have a greater flaccidity profile that leads to a more natural-type erection.

The ideal penile prosthesis will permit a man to control when he has an erection and will allow penile flaccidity and erection that approximate their natural counterparts as closely as possible. To achieve these goals, fluid must be transferred into expandable cylinders for erection and must back out of the cylinders for flaccidity. A device with a fluid reservoir is required, thus necessitating placement of the reservoir in the retropubic space, although it may be placed in the peritoneal cavity when such an extraperitoneal space does not exist.

Placement of the fluid reservoir into a submuscular location that is posterior to the rectus abdominis muscle but anterior to the transversalis fascia has been described as a means of safely placing three-piece devices in men with prior pelvic surgery.[1] Stember et al. reported a higher rate of reservoir herniation and revision for palpable reservoir utilizing this submuscular technique as opposed to a traditional placement in the retropubic space.[2]

It is our practice to place a three-piece device where possible. We routinely use the Coloplast device; however, other centers use the AMS three-piece device with excellent results. In certain populations we consider implanting the Ambicor two-piece device (Box 52.1). Other authorities use three-piece devices in some of these populations with both excellent safety and satisfaction.

In men who have a fibrotic penis and who are undergoing secondary (repeat) prosthesis implantation, it is our practice to implant a narrow three-piece device, usually in conjunction with the use of a Cavernotome (UROAN 21, Baleares, Spain) or sharp corporal tissue excision. Surgeons in centers that use AMS 700 devices suggest that in men who have had previous cylinder erosion or crossover, CX/CXR rather than LGX cylinders should be used because avoidance of length expansion (as can occur with the LGX device) in these situations is preferable.

The advantages of two-piece over three-piece devices are explained to the patient to enable him to make a more informed choice. We insist that all patients read the device-related literature, view videos of the device, and speak to a patient who has undergone implant surgery. Our patients also have a routine lengthy counseling session with the implant surgeon before they commit to the procedure. Ensuring that the patient has realistic expectations before implant surgery is undertaken is essential to ensuring high postoperative satisfaction profiles. Specifically, we discuss infection rates, rates of reoperation, and the lack of penile length increase with penile prosthesis surgery.

Infection

Infection associated with prosthetic surgery is a significant problem. The reported incidence of initial penile prosthetic surgical infections is between 1% and 8% (Table 52.1).[3,4] Modern techniques with antibiotic-coated devices have brought the infection rate to approximately 1%.[5] Investigators have reported an increase in this rate with second and third reoperative procedures.[6] Additionally, the risk of prosthetic infection is also increased in patients with poorly controlled diabetes mellitus (glycosylated hemoglobin >11.5%), spinal cord injuries, or a history of urinary tract infection.[7–12]

Table 52.1 Infectious Complications of Penile Prosthesis

First Author	Year	No. Patients	Infection Rate (%)
NONCOATED			
Montague	1987	15/556	2.7
Radomski	1992	2/107	1.9
Wilson	1995	24/823	2.9
Jarow	1996	2/114	1.8
Garber	1998	6/360	1.7
Wislon	1998	15/333	4.5
Montague	2001	7/285	2.5
Carson	2004	31/1944	1.6
Wolter	2004	10/482	2.1
Drogin	2005	3/94	3.2
ANTIBIOTIC COATED			
Carson	2004	15/2261	0.7
Abouassaly	2006	1/55	1.8
Wilson	2007	1/83	1.2
Dhabuwala	2011	9/339	2.7
Shaw	2011	1/100	1.0
Eid	2012	16/1858	0.9
Villaeal	2012	1/48	2.1
Song	2013	1/201	0.5
Stember	2014	8/131	6.1
Antonini	2016	3/180	1.7

Skin-dwelling bacteria are usually responsible for operative wound contamination. Historically, the most common bacterium associated with penile implant infection is *Staphylococcus epidermidis*. A recent review of infected prostheses at 25 institutions revealed that 73% of positive cultures grew gram-positive bacteria, 39% grew gram-negative organisms, and 25% grew multiple organisms.[13] Highly virulent organisms such as methicillin-resistant *S. aureus* (MRSA), *Pseudomonas aeruginosa*, *Enterococcus* species, *Prevotella* species (*Bacteroides* subspecies), and fungi have been associated with penile implant infections. Patients with infected penile implants usually present between 1 and 8 weeks postoperatively with fever, pain, and swelling overlying the prosthesis often (but not always) accompanied by purulent wound drainage. Other signs and symptoms of a developing infection are persistent pain over parts of the implant on palpation, elevated white blood cell count, elevated erythrocyte sedimentation rate, cellulitis, fever, chills, erosion (Fig. 52.4), or fixation of parts of the prosthesis (tubing or pump) to the scrotal wall. Although it is uncommon, infection may manifest after 8 weeks within the first year after the surgical procedure. Such an infection is usually caused by *S. epidermidis* and manifests in an indolent fashion.

Anecdotally, reports have noted implant infection occurring years after implantation. This phenomenon is believed to result from hematogenously disseminated bacteria leaked into the bloodstream after a surgical or dental procedure. Carson and Robertson described a series of delayed prosthetic infections presumably caused by hematogenous bacterial spread from a remote focus.[3] All six patients underwent uncomplicated prosthesis implantations and had an extended problem-free period of use before the inset of infection. All the devices in this series were explanted.

If the penile prosthesis is infected, it must be removed. Systemic administration of antimicrobial agents alone is ineffective in destroying all offending bacteria. On an



Figure 52.4 Eroding implant cylinder through urethral meatus.

ultrastructural level, biofilm produced by bacteria surrounds the implanted device and thereby radically reduces the ability of antimicrobial agents to penetrate the area where the bacteria are located.[14] Additionally, the human body produces a fibrotic capsule that surrounds the prosthesis. This fibrotic capsule has minimal blood supply, a feature that also reduces the efficiency of antibiotic penetration.

Once the prosthesis is removed, the surgeon must decide whether to reimplant another prosthesis several months later or to perform a salvage procedure. Traditionally, following removal of the prosthesis, the area is copiously irrigated with antibiotic solution. Some experts leave drains in place, and the incision is closed. This appears to be a matter of choice because no evidence-based medicine has addressed this issue. Based on intraoperative wound and blood cultures, the patient is treated with appropriate systemic antimicrobial agents. If placed, drains may be irrigated two to three times per day with antibiotic solution for several days. A new penile prosthesis may be reinserted 2–6 months later.

An alternative approach is to reimplant a new prosthesis immediately, during the same operative session as the explantation. Procedurally, all parts of the infected prosthesis are removed, the wound is copiously irrigated with a series of antibiotic or antimicrobial solutions, the patient is prepared and draped again, and the new prosthesis is inserted.[15] The benefit is that this approach allows for easier cylinder insertion and abrogates the penile shortening that occurs secondary to corporal fibrosis if the cylinders are removed and are not immediately replaced.[15,16] Mulcahy reported long-term success in 45 of 55 (82%) men who underwent salvage of their penile prostheses in the setting of infection.[16]

Occasionally, the surgeon may determine that only the prosthesis cylinder or pump is infected, not the reservoir. In this instance, although it is controversial, we have on occasion attempted and succeeded in salvaging only the cylinders (acting as stents to prevent penile shortening) and returned later for pump and reservoir placement. Exclusion criteria proposed for salvage include any degree of being immunocompromised, sepsis, tissue necrosis, and copious amounts of pus within the corporal bodies.[15] Other relative indications are erosion of the cylinders and the presence of uncontrolled diabetes. Habous et al. have also reported conservative therapy utilizing oral antibiotics in 37 men with localized infection.[17] However, this approach should only be used in highly compliant patients who understand that this is not the standard of care.

In 2001, Montague and colleagues conducted a retrospective review of 491 patients who received a three-piece inflatable penile prosthesis.[18] These investigators reported infection rates and risk factors in these recipients. Of the 491 total patients, 10 infections (2.0%) occurred. Seven of the infections were in first-time prosthesis recipients and three were in recipients of secondary inflatable penile prostheses. The presence of diabetes played a minor role in the development of inflatable penile prosthesis infection because three of the total 10 infections were in the 137 men with diabetes mellitus. The remainder of infections occurred in patients who did not have diabetes. Surprisingly, this study did not find statistically significant differences in infection rates between first-time and secondary prosthesis recipients or between diabetic and nondiabetic recipients, findings dissimilar to the conclusions published in studies by Jarow[4] and by Lynch and colleagues.[19]

Jarow reported a higher infection rate in patients undergoing a secondary procedure for corporal reconstruction versus prosthesis revision versus first-time insertion of an inflatable penile prosthesis (21.7% vs 13.3% vs 1.8%).[4] This finding is in contrast to the results of the study by Montague and associates.[18] Jarow found convincing evidence not only that reoperation is associated with higher rates of device-related infections but also that complex corporal reconstruction further increases the chance of postoperative infection of inflatable penile prostheses.[4]

Diabetes mellitus, a reported risk factor for the development of implant infections, has been the subject of articles by luminaries in the field of sexual medicine. One of the first reports in the modern era noted a 22% incidence of infection in patients with diabetes but a 6.7% infection rate in patients who did not have diabetes.[19] Subsequent reports by Wilson and colleagues failed to link diabetes (regardless of mean glycosylated hemoglobin levels) to a higher risk of prosthesis infection.[20,21]

Given that many prostheses are implanted by low volume surgeons, population-based studies are useful for capturing outcomes potentially incongruent with those reported by high volume surgeons. Utilizing a New York State database of 14,969 men, Onyeji and colleagues reported infectious complications in 2.3% of implants.[22] Grewal et al. reported on 1824 virgin penile implants using a California database and found a 3.2% infection rate.[23]

ANTIBIOTIC-IMPREGNATED PROSTHESES

In an effort to decrease the rate of prosthetic-associated infection, specially modified implants have been developed. AMS introduced InhibiZone prostheses (which are coated with rifampin and minocycline), and Coloplast marketed a device with a low-friction, antibiotic-absorbing coating on its Titan prostheses. In nonrandomized studies, both these coatings were shown to decrease the incidence of implant-related infections.

Carson in 2004 retrospectively reviewed the difference in infection rates between patients who received AMS penile implants impregnated with a combination of rifampin and minocycline and those who received untreated prostheses.[24] He reported that the infection rate was initially 1.59% in the noncoated implant and it decreased to 0.2% at 12 months in the coated implant.[24] These data are based on the use of patient information forms completed at the time of the surgical procedure by the surgeon. Thus, these data are not generated from a randomized study, nor is the surgeon blinded to the device type.

In 2006, Abouassaly and colleagues assessed the impact of prosthesis replacement for mechanical failure on infection rates with an AMS antibiotic-coated prosthesis (coated with rifampin and minocycline).[25] Although the investigators excluded salvage procedures for clinically infected prostheses, one of 55 patients experienced postoperative device infection in the 32-month follow-up period. The investigators concluded that insertion of an antibiotic-coated inflatable penile prosthesis may result in lower infection rates in this cohort of men.[25]

In a large study, Wilson et al. reported that InhibiZone-coated inflatable penile prostheses showed reduction in infection in multiple scenarios.[26] Specifically, in 467 patients receiving InhibiZone-coated implants, no infections developed among the 223 first-time implants in nondiabetic patients, one of 83 diabetic patients developed an infection, four infections were found in 39 patients who underwent implant revisions, and infections developed in four of 123 men when a salvage operation was combined with antibiotic washout.[26]

The impact of antibiotic coating on infection rates is also supported by population-based studies. Onyeji et al. reported that the infection rate in New York State decreased from 4.2% in the era before antibiotic coating was used to 1.5% afterward.[22]

Mechanical Malfunction

Although infection may be the most serious penile prosthetic complication, mechanical malfunction remains the most frequent reason for reoperation (Table 52.2).[27] Common reasons for malfunction are cylinder aneurysm, tubing leakage, reservoir leakage, cylinder leakage, and connector fracture. Failure rates have been reported to be 15% at 5 years and 30% at 10 years.[28] In the event of malfunction, we believe that replacement of the entire device is prudent if initial insertion occurred >2 years previously, because this approach will increase the likelihood of longevity of the device. Frequent updates and revisions of the penile implant devices make it difficult to ascertain their true mechanical longevity scientifically.

Levine and colleagues retrospectively reviewed reliability, complication, and patient satisfaction rates in 131 men with the two-piece AMS Ambicor penile prosthesis.[29] Ten patients had complications, six of which resulted from mechanical failure. The Ambicor penile prosthesis historically has had high satisfaction rates coupled with reliable function.

A review by Carson and associates of the reliability of and satisfaction with the AMS 700 CX three-piece penile prosthesis encompassed a median follow-up of 47.7 months and had two phases.[28] Phase 1 reviewed the medical record of 372 patients and phase 2 was a telephone interview of 207 patients. Medical record review found that the devices were functionally reliable 92.1% of the time after 3 years and 86.2% after 5 years. Seventy-nine percent of the patients with a device used it at least twice monthly, and

Table 52.2 Mechanical Reliability of Penile Prosthesis

First Author	Year	No. Patients	Type of Prosthesis	Mechanical Failure (%)
Fishman	1984	113	AMS 700	1.8
Hackler	1986	46	Mentor 3 piece	0
Wilson	1988	29	AMS 700	14
Furlow	1988	120	AMS 700	8.3
Merill	1988	301	Mentor 3 piece	6
Knoll	1990	94	AMS 700 CX	6.4
Sternkohl	1991	46	Mentor 3 piece	28
	1991	43	AMS 700 CX	5
Fein	1992	80	Mentor Mark II	0
Wilson	1993	64	Mentor 3 piece	18.8
Lewis	1993	275	AMS 700 CX	4.7
Quesada	1993	214	AMS 700 CX	1.9
Goldstein	1993	112	Mentor Alpha I	3.6
Lewis	1995	56	Mentor Alpha I	1.8
Wilson	1999	410 971	Original Mentor Alpha I Enhanced Mentor Alpha I	5.6 1.3
Montorsi	2000	200	AMS 700 CXM	4
Young	2001	273	AMS 700 CXM	7.3
Levine	2001	131	Ambicor	4.6
Dhar	2006	455	AMS 700 CX/CXM	19
Wilson	2007	2384	AMS 700 CX	32
Kim	2010	113	AMS 700 CX/CXM	12
Song	2013	201	AMS 700 CXM	2
Ji	2015	74	AMS 700 CXM	13.5

88.2% would recommend an implant to a relative or friend. The investigators concluded that the AMS 700 CX penile implant was reliable, provided excellent patient and partner satisfaction, and had a low postoperative morbidity profile.[28]

Ferguson and Cespedes prospectively evaluated the long-term reliability of and patient satisfaction with the AMS Dura-II malleable penile prosthesis.[30] In this study, the 94 patients who underwent implantation with the Dura-II device were prospectively examined and asked to complete standardized questionnaires regarding sexual activity, prosthesis function, intercourse satisfaction, and overall quality of life. During the follow-up period of nearly 6 years, 76% and 87% of patients reported satisfactory rigidity and ease of concealing the device, respectively. Quality of life was enhanced by the implant in 87% of men, and 88% would recommend this prosthesis to a friend. Malleable penile prostheses appear to be as effective and satisfactory as are fluid-filled models. Patient selection and recipient expectations undoubtedly play large roles in determining the likelihood of a satisfactory outcome.

Wilson and associates published a large, long-term, historical prospective study of 2384 patients to estimate mechanical and overall revision-free survival of four different inflatable penile prostheses (Mentor Alpha 1, Mentor Alpha NB, AMS 700 CX, and AMS 700 Ultrex).[31] At 10 and 15 years, mechanical reliability was 79.4% and 71.2%, respectively. More recent Mentor Alpha models improved 10-year survival to ≤88.6%. The newer iterations of the AMS CX devices had a reported 97.9% freedom from mechanical breakdown at 3 years. This large study conducted in 2007 further lends credence to the excellent mechanical durability of modern inflatable penile prostheses. Ji et al. reported similar long-term mechanical reliability rates of 76.5% and 64.8% at 10 and 15 years, respectively, using the AMS CXM model in 74 patients in Korea.[32]

Onyeji and associates reported a noninfectious reoperation rate of 4.1% in 14,969 implants done in New York State with a median follow-up of 95.1 months.[22] Grewal et al. reported a similar 4.17% revision rate for noninfectious causes in 1824 cases; however, their follow-up was at most 4 years, with no reported median.[23]

In an effort to elucidate the chronology of patient satisfaction after implantation of a penile prosthesis, we prospectively evaluated men with the International Index of Erectile Function (IIEF) questionnaire preoperatively as well as at 3, 6, and 12 months postoperatively. The investigators also administered the Erectile Dysfunction Inventory of Treatment Satisfaction (EDITS) questionnaire postoperatively at 3, 6, and 12 months. The study of 96 men found that 6- and 12-month scores were higher than baseline, but satisfaction was statistically higher at 12 months as measured by the IIEF satisfaction domain. This first-of-its-kind study elucidated that satisfaction with penile implant further increases after 6 months, but more importantly it provided physicians with additional information to impart to patients.[33]

Erosion

Erosion of a component of the prosthesis is not rare. The device can erode through skin (cylinder or reservoir) or erode through tunica (cylinder), such that it lies subcutaneously. When erosion through skin occurs, the device is inherently infected and probably eroded in the first place because of a low-grade infection. Our approach to this complication depends on the nature of the erosion.

Erosion of the corporal cylinders extracorporally through the distal portions of the corporal bodies may occur iatrogenically from overenthusiastic corporal dilation or oversizing of the cylinders.[34] Patients with decreased distal sensation such as those with spinal cord injury or diabetes mellitus may have an increased incidence of distal erosion.[35] In addition, we have seen this complication in patients who have received previous pelvic irradiation.

Techniques of distal corporal erosion repair include creation of a new pocket for the tip of the cylinder through a hemicircumferential incision for established or impending distal erosion. In cases of lateral extrusion of corporal cylinders, Mulcahy described the creation of a new corporal cavity to reseat the prosthetic device.[36] In this situation, a hemicircumcising incision is made and the cylinder tip is exposed. Next, a 3-inch lateral longitudinal corporotomy is made proximally over the cylinder. The back wall of the fibrotic sheath is then incised transversely and a new plane of dissection is developed. Finally, the cylinder is inserted into this new cavity.

Crural Perforation

Proximal (crural) perforation is not uncommon, although no data exist in the literature. This complication usually results from overly vigorous or misdirected proximal dilation such that the dilating instrument perforates the tunica and lies in the perineum. If perforation is noted intraoperatively, no long-term concern exists, but failure to identify this complication at the time of implantation may result in proximal migration of the cylinders out of the glans and into the perineum.

Certain surgical approaches are aimed at preventing proximal slippage of the cylinder without direct repair of the crural tunica. Historically, this goal has been accomplished by wrapping the proximal end of the cylinder in a "windsock" made of either synthetic or available natural material such as cadaveric pericardium or intestinal submucosa (Fig. 52.5). This windsock is then sutured to the tunica to prevent proximal migration of the cylinder. A second method is to suture the rear-tip extender (if used) to the corporal tunica with nonabsorbable monofilament suture. The cylinder of the prosthesis is then securely seated into the rear-tip extender. A newer approach to this problem is the simple use of a suture hammock around the exit tubing at the proximal end of the cylinder. A simple U-type suture in this setting prevents proximal cylinder migration.

Supersonic Transporter Deformity

The supersonic transporter (SST) deformity is the name given to the glans of the penis when it appears to bend or hang most commonly downward (but also occasionally upward) limply from the erect penile shaft. This condition

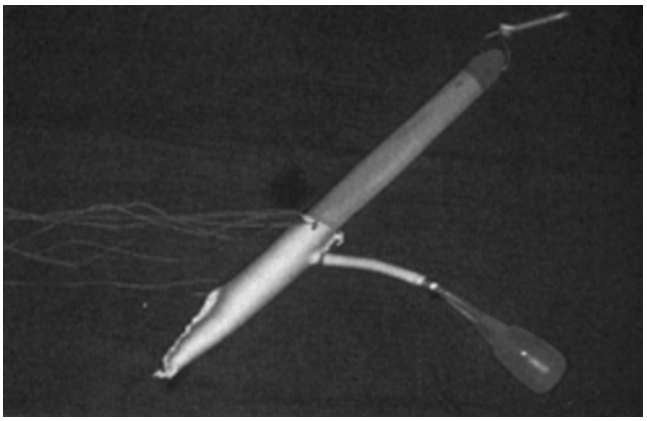


Figure 52.5 Fashioning a windsock around the rear end of the cylinder to prevent proximal migration in the setting of crural perforation. The windsock contemporarily uses an off-the-shelf material such as cadaveric pericardium or intestinal submucosa.

may lead to difficulty with penetration or irritation of tissue overlying the ends of the corporal body. The deformity may be the result of inappropriately sized implant cylinders, inadequate distal corporal dilation, or a constitutionally hypermobile glans. This issue may be remedied through a subcoronal incision and dissociation of the glans penis from the distal ends of the corporal bodies. With care taken to avoid neurovascular bundle injury, the glans is then repositioned more proximally on the corporal bodies and is fixed using two nonabsorbable sutures (No. 1 polyester, Ti-Cron, Tyco Healthcare, Waltham, MA) placed on either side of the midline in a horizontal mattress fashion. These sutures are ideally placed through the tunica albuginea on the corporal body and through the fascial layer on the undersurface of the glans penis.[37,38]

Penile Necrosis

The most devastating complication following penile prosthesis insertion is penile necrosis. This rare complication is most often precipitated by local infection; however, pressure dressing or the prolonged presence of a urethral catheter may contribute to the development of necrosis.[39] Adherence to the following basic principles may help avoid this issue:

1. Rigorous sterility of the operative field
2. Limited use of an indwelling catheter
3. Avoidance of circumferential penile compression bandages
4. Proper sizing of penile corporal cylinders
5. Avoidance of prolonged cylinder inflation.

Although we have no way to predict who will develop this problem, aggressive treatment may be lifesaving. The prosthesis should be removed, the corporal bodies irrigated, and necrotic tissue debrided. Care must be taken to preserve as much viable tissue (and to avoid amputation) as possible for future penile reconstruction. In the setting of superficial penile gangrene, avoidance of prosthesis removal may be possible but is not recommended.[40] Perfusion and healing may be enhanced with hyperbaric oxygen, warm compresses, or vasodilators, although no data exist in the medical literature on these strategies and thus they are purely empirical.

Complications of Penile Vascular Surgery

Vascular surgery encompasses penile revascularization and crural ligation surgery for venous leak. Vascular surgery is the only treatment modality that has the potential to allow the permanent return of spontaneous erections without the need for pharmacologic or device support. Specifically, the goal of the surgical procedure is to increase the cavernosal arterial perfusion pressure and inflow in patients with erectile dysfunction resulting from pure arterial insufficiency. The ideal patient is a young man with pure arteriogenic erectile dysfunction who has no other vascular risk factors.

Penile revascularization has undergone many refinements since its first description by Vaclav Michal and associates in 1973.[41] Many variations have been described by Michal and associates,[42] Virag,[43] Hauri, Crespo and colleagues,[44] and Hatzichristou and Goldstein.[45] No further revolutionary changes have occurred in the realm of penile revascularization surgery, nor does consensus exist among experts with regard to the definitive technique.

Complications of penile revascularization occur in approximately 25% of patients.[46–48] Postoperative arterial hemorrhage with hematoma formation may result from disruption of the microvascular anastomosis. This is the culmination of the repetitive stretching and tearing of the vascular anastomosis during coitus or masturbation. In our practice, we recommend abstention from sexual activities involving an erect penis for at least 6 weeks postoperatively.

Another rare complication is glans hyperemia, which occurs when the dorsal vein has been arterialized (inferior epigastric artery or dorsal artery to deep dorsal vein anastomosis).[46,48] The treatment is to ligate the deep dorsal vein distally. Diminished penile sensation may result from dorsal nerve injury but is uncommon because an operating microscope is used for dorsal vessel dissection.[49]

Crural ligation for venous leak has seen a resurgence in use at major referral centers. In an effort to correct isolated venous leak from crural veins, this procedure entails ligation (or exclusion) of the proximal corpora with umbilical tape.[50,51] Two of the more influential studies of this procedure are by John Mulhall and Tom Lue and their associates. Mulhall and colleagues[50] described success using a transscrotal approach, whereas Lue and colleagues[51] favored a 3-inch inguinoscrotal approach. The most common complications in these studies were scrotal hematoma, infection, and continued erectile dysfunction. We had a single case of infection of the umbilical tape, which was removed. We now treat all patients with preoperative, perioperative, and postoperative oral antibiotics.

Peyronie's Disease Surgery Complications

Peyronie's disease is a fibrotic disorder of the tunica albuginea that results in penile deformity, penile pain, and, in

some patients, erectile dysfunction.[52] The etiology and pathophysiology of this disorder have not been completely elucidated.[53–55] Prevalence estimates range from 1% to 8.9%.[56,57] The natural history of Peyronie's disease was initially described by Williams and Thomas in 1970.[58] In this small study, the investigators reported a spontaneous resolution rate of 50%.[58] As a result of this study, many patients with Peyronie's disease are prescribed conservative treatment. In a later report, Gelbard and colleagues described resolution of penile curvature in 13% of patients with nonsurgical treatment.[59]

In 2006, we reported an analysis of the natural history of Peyronie's disease in 246 untreated patients.[60] Mean follow-up was 18 months, at which time 12% of men had an improved curvature, 40% remained stable, and 48% worsened. The most important information from this report is that the average improvement in curvature was 15 degrees, but in patients who experienced worsening of curvature, the mean change was 22 degrees. These and other articles suggest that spontaneous resolution of penile curvature from Peyronie's disease is uncommon.

Peyronie's disease has two phases: acute (inflammatory) and chronic. It is best to correct the penile deformity surgically after the acute phase has passed. Typically, this is 12 to 18 months after the onset of the condition. In the chronic phase, the penile curvature has stabilized and, although penile plaque may be prominent and calcified, it is not associated with penile pain. This is the optimal time for surgical intervention.

INDICATIONS

Tornehl and Carson published criteria for the surgical intervention of Peyronie's disease.[61,62] In our practice, we communicate to patients that no absolute indications exist for curvature correction. However, if the patient can answer any the following questions in the affirmative, if he is ≥12 months from the initial onset of symptoms, and if he has had a stable deformity for ≥3 months, he is then considered to be a candidate for surgical correction of the penile deformity:

1. Does the patient hate the appearance of his penis?
2. Is the patient unable to have penetrative sexual relations?
3. If the patient is able to have penetrative sexual relations, is the experience cumbersome or unsatisfactory?

INTRALESIONAL TREATMENTS

While surgical treatment of Peyronie's disease offers correction of the deformity in a single treatment session, the less invasive nature of intralesional treatments may appeal to some patients. Intralesional therapies come in the form of verapamil, interferon alfa-2b, and collagenase *Clostridium histolyiticum*. Only intralesional collagenase clostridium histolyticum is FDA approved for treatment of Peyronie's disase.

Intralesional verapamil is a calcium channel blocker thought to inhibit fibroblast formation. Evidence for its use in treating stable disease is mixed.[63] However, it can be used in the acute phase, resulting in stabilization of curvature in 60% of patients and reduction of curvature in 20% of men.[64] Complications include pain at the site of injection in 15% of men, bruising in 25% of men, and a 10% rate of dizziness/nausea.[63]

Intralesional interferon alfa-2b is a cytokine thought to inhibit the proliferation of fibroblasts. It reduces penile curvature by 13.5 degrees and is indicated in men with stable disease, curvature >30 degrees, and no plaque calcification.[65] Patients should be counseled that 40–100% of men will have flu-like symptoms and minor penile swelling.[63]

Intralesional collagenase clostridum histolyticum is indicated in men with stable disease and curvature >30 degrees and less than 90 degrees. The average improvement in curvature is 35%, with 75% of men achieving a >25% curvature improvement.[66] Adverse events are experienced by 85% of men and include bruising in 80%, swelling in 50%, and penile pain in 50%. Additionally, 0.5% of men experience corporal rupture, hence the recommendation for 2 weeks without sexual activity after each treatment.

PROCEDURES

Once the decision to proceed with operative intervention has been made, the surgeon must choose the most appropriate method of curvature correction based on physical examination (nature and magnitude of deformity) during maximal rigidity erection, baseline erectile function, and penile dimensions. Surgical procedures for correcting curvature resulting from Peyronie's disease fall into three major categories. For a full review of these categories, the reader is referred to the article by Tornehl and Carson[62] in *Urologic Clinics of North America*:

1. Plication: Nesbit, 16-dot, corporoplication, Kelami's corporoplasty, or incisional corporoplasty, Yacchia procedure
2. Plaque manipulation: removal or incision of the plaque with subsequent coverage of the corporal defect with synthetic or nonsynthetic graft material
3. Penile prosthesis insertion.

Selecting the correct surgical approach for the individual patient is critical to optimizing results. Patients with complex deformities or those who have at baseline a foreshortened penis are not good candidates for penile plication surgery. Patients with preexisting erectile dysfunction or low-degree simple curvatures are not excellent candidates for plaque incision and grafting surgery. Patients with normal erectile function should probably not undergo penile implant surgery unless they have a complex deformity or a significant hourglass deformity.

Plication-type procedures are best used in the patient with congenital penile curvature. This approach has a short surgical time, is relatively simple, and has little impact on existing erectile capacity. Plaque manipulation techniques are used in patients with complex deformities, hourglass deformities, normal erectile function, or preexisting penile shortening. Unfortunately, the disadvantages of this method are degeneration of erectile function or dysfunction and dorsal nerve entrapment or damage leading to penile neurosensory alterations. The use of a penile prosthesis in Peyronie's disease is reserved for men with preexisting

moderate-to-severe erectile dysfunction who have unsuccessfully tried oral and injectable agents.

PENILE PLICATION COMPLICATIONS

Complications of plication procedures include hematoma formation, decreased penile sensation (anesthesia, dysesthesia), erectile dysfunction, and bother from suture material palpable after the operation. We perform all dorsal plication procedures after neurovascular bundle elevation.[67,68] This approach minimizes the risk of decreased penile sensation in the postoperative setting. We recommend incising Buck's fascia and using loupe magnification to visualize the dorsal penile nerve bundles. We also use braided nonabsorbable suture (No. 1 polyester [Ti-Cron]) when performing plications because this material is less palpable and may reduce the incidence of patient bother from suture knots.

In 1998, Pryor reported data from 359 patients dating from 1977 to 1992 who had penile plication performed using the Nesbit technique.[69] The investigators convincingly argued that this technique translates into a high patient satisfaction rate (≤90%) while minimizing postoperative complications. These investigators found that Nesbit-related penile shortening was not a significant problem in this patient population; only six men were unable to have penetrative sexual relations because of this issue.[69]

A more contemporary series of 68 patients from Spain confirmed the findings of other reports.[70] At 36 months of mean follow-up, 20% of patients had penile shortening of >1.5 cm, but 85% of the men were satisfied with the cosmetic result of Nesbit technique. Complications of the surgical procedure were minimal; two men developed phimosis, and two needed a second procedure for recurrent curvature.[70] Pertinent results of these and other studies are contained in Table 52.3.

PLAQUE MANIPULATION SURGERY

The risk of complications from plaque-based surgery is low. Initial complications include hematoma (supragraft and subgraft) formation and, rarely, infection. Hematoma formation may be limited by the use of watertight suture lines, small-diameter suture needles, and narrow-gauge needles when erectogenic drugs are administered to generate an artificial erection. Intermediate and late complications are penile skin necrosis, penile length loss, and recurvature. Loss of penile skin, although rare, is caused by the circumferential skin incision. Because the skin of the penile shaft and the skin of the glans have a separate but anastomotic blood supply, we advocate the use of a single circumcising incision. If needed, a transverse scrotal incision can be made in addition to provide access to the proximal corpora.

The recurrence of curvature within a short period postoperatively is the result of either suture failure (we use 4-0 polydioxanone [PDS]) or an inadequately sized graft. Nonabsorbable or delayed-absorption suture must be used in grafting because the tunical forces developed during an erection far exceed the tensile strength of partially absorbed polyglactin (Vicryl, Ethicon, Somerville, NJ) or synthetic polyester (Biosyn, Syneture/US Surgical, Norwalk, CT).

The choice of the best grafting material has been the subject of quiet debate. Synthetic materials (e.g., Gore-Tex) are of historical significance because autologous and cadaveric (processed, prepackaged) grafts are readily available and provide fewer complications. Autologous material (e.g., buccal, dermal, tunical, vein), although available, incites minimal host reaction and infection risk and requires an auxiliary procedure to harvest.

An Italian group led by Montorsi assessed the long-term outcome of vein grafting in 50 patients with Peyronie's disease.[71] After a mean follow-up of 32 months, complete resolution of penile curvature in 40 men (80%), minor

Table 52.3 Outcomes of Penile Plication

First Author	Year	No. Patients	Mean Follow-up (mo)	Shortening (%)	Recurrence (%)	Satisfaction (%)
Sulaiman	1994	78	50	NR	4	18
Ralph	1995	185	180	NR	3	90
Savoca	2000	157	72	14	NR	88
Gholami	2002	132	31	41	15	85
Syed	2003	42	84	76	10	50
Savoca	2004	218	89	17	NR	83.5
Bokarica	2005	40	81	100	NR	NR
Moyano	2006	68	36	20	2.9	85
Greenfield	2006	68	29	NR	NR	98.5
Taylor	2008	90	72	69	NR	93
Hudak	2013	154	14	78	NR	95
Cantoro	2014	89	103	22.5	NR	91
Papagiannopoulos	2015	159	17	NR	17.4	93.8

residual curvature of ≤30 degrees in seven men (14%), and recurrence of curvature in three men (6%) were reported. The procedure was complicated by penile hypoesthesia, penile hematoma, wound infection, and glandular ischemia. Plaque incision with vein grafting is able to achieve satisfactory clinical results for a majority of men.[71] Wimpissinger et al. reported on 10-year outcomes of 30 men who underwent grafting with vein and 43.3% reported perceived penile shortening, 20% experienced penile hyposensitivity, and 23% experienced disease recurrence.[72]

As opposed to autologous grafts, processed or prepackaged material (pericardium, dura mater, intestinal submucosa) offers the ability to tailor the graft specifically to the appropriate size, minimizes the host inflammatory response, and abrogates the need for harvesting tissue. Levine and Estrada published their experience with human cadaveric pericardium.[73] Over a 4-year period, 40 men underwent penile curvature correction with pericardium. Postoperatively, 98% of these men had a straight penis and 95% were able to have penetrative sexual relations; 12 (30%) patients required pharmacologic assistance to achieve a penetration-quality erection. Most interesting is that no major complications occurred in this cohort of men.[73]

Breyer and Lue and their colleagues[74] retrospectively reviewed outcomes with and complications of using intestinal submucosa in the correction of penile curvature in Peyronie's disease. Nineteen patients were treated with tunical incision or excision and grafting with small intestine submucosa. Of these patients, 37% (seven of 19) had significant recurrent penile curvature, whereas five of 19 (26%) had recurrent Peyronie's disease plaque. The investigators reported a 37% complication rate, including graft site hematoma and graft infection, as well as reoperation for Peyronie's disease recurrence in a single patient.[74] Despite the ease of use of small intestine submucosa, the high complication rate makes the use of this material less desirable. The results of these and other studies are presented in Table 52.4.

PENILE PROSTHESIS SURGERY

Implant surgery for Peyronie's disease is indicated when the patient has both Peyronie's disease and erectile dysfunction that is not responsive to erectogenic pharmacotherapy. General complications of penile prosthesis insertion are listed elsewhere, but penile modeling deserves special comment. Modeling or molding entails powerfully bending the penis in an effort to break or crack the Peyronie's plaque when residual curvature remains after inflation of the device intraoperatively. This method was embraced by Wilson and Delk in 1994 and showed an initial 86% success rate.[75]

The specific technique is begun with the device partially inflated and the tubing cross-clamped with rubber shod hemostats. The penis is forcibly bent in a direction opposite to the curvature in a maneuver similar to breaking a twig in both hands for 90 seconds. The procedure is repeated for another 90 seconds. The device is deflated and then reinflated to reseat the cylinders within the corporal bodies.[76] Certain devices are ill advised when penile modeling may be required. The AMS Ultrex, with its girth- and length-expanding capabilities, may cause an increased risk of aneurysm formation when forcibly deformed. Furthermore, the Ultrex device lacks the axial rigidity to straighten a penile curvature.[77] Follow-up studies by Wilson and associates confirmed that implantation and modeling appeared to provide permanent straightening without an increase in revisions as compared with implantation alone.[76]

The major complication of corporal modeling is urethral laceration, which occurs in approximately 4% of cases.[76] This ulceration is usually visible and is repaired using fine absorbable sutures (Table 52.5).

Concomitant use of penile plication or plaque manipulation and penile prosthesis may be helpful in men with more significant Peyronie's disease and ED. Egydio and associates reported a 4.8% rate of decreased sensation and a 1% rate of infection in men who had circular and longitudinal

Table 52.4 Outcomes of Plaque Incision and Grafting

First Author	Year	No. Patients	Graft	Length Loss (%)	Correction Rate (%)
Kadioglu	1999	20	Vein	NR	75
Montorsi	2000	50	Vein	40	80
Knoll	2001	12	Intestine	0	100
Egydio	2002	33	Pericardium	NR	88
Levine	2003	40	Pericardium	NR	98
Lue	2007	19	Intestine	63	63
Knoll	2007	162	Intestine	5	91
Hsu	2007	48	Vein	NR	90
Taylor	2008	81	Pericardium	59	91
Sanalone	2011	157	Pericardium	NR	88
Papagiannopoulos	2015	113	NR	NR	81.6
Yafi	2016	26	Fibrin	NR	85
Wimpissinger	2016	30	Vein	43.3	86.7

Table 52.5 Outcomes of Penile Implant Surgery for Peyronie's Disease

First Author	Year	No. Patients	Manual Modeling (%)	Successful Correction (%)	Device
Levine	2000	46	54	100	Two- and three-piece
Wilson	2001	104	100	NR	Alpha 1, 700 CX
Usta	2003	42	74	26	NR
Akin-Olugbade	2005	18	20	100	NR
Levine	2010	90	79	79	Two- and three-piece
Garaffa	2011	129	29.1	84	Titan or AMS 700
Chung	2013	138	NR	92	Titan or AMS 700
Papagiannopoulos	2015	62	NR	90.3	NR
Yafi	2016	24	80	100	Titan or AMS 700

grafting.[78] Rolle et al. reported a 3.5% significant bleeding rate and 7% infection rate in 28 men who had severe penile shortening and underwent a sliding technique.[79]

Conclusions

Penile prosthesis insertion is associated with patient high satisfaction rate. Infection of a penile prosthesis and malfunction are the most common postoperative complications; however, advances in both device technology and surgical technique continue to lower the rates of these complications. Surgeons must also be aware of and know how to navigate other intraoperative and postoperative complications such as crural perforation, erosion, and drooping of the glans.

Surgical management of Peyronie's disease continues to play a vital role in the management of the disease. The complications associated with each of the surgical management options is an important factor in deciding which approach to take with each patient. Penile length, baseline erectile function, and degree of deformity are important factors to consider in counseling which surgical technique is most appropriate for any individual patient.

References

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Chapter 52 Questions

1. What are the most common organisms that are associated with penile prosthesis infections?
   a. Multiple organisms
   b. Gram-negative organisms
   c. Gram-positive organisms
   d. Anaerobes
   e. Fungi

2. In the placement of a malleable penile prosthesis, during salvage of infection, which of the following principles is associated with penile necrosis?
   a. Limited use of an indwelling catheter
   b. Proper sizing of the corporal cylinders
   c. Circumferential penile compression bandage to minimize hematoma
   d. Rigorous sterility of the operative field
   e. Minimized prolonged cylinder inflation

Case Study 1

A 65-year-old man with a history of insulin-dependent diabetes and renal transplant has erectile dysfunction (ED) nonresponsive to PDE5 inhibitors and intracavernosal injections. He elects implantation of a penile prosthesis.

1. What device and technique has the highest rate of complications in this setting?
   a. 2-piece penile prosthesis
   b. 3-piece penile prosthesis with retropubic placement of the reservoir through the inguinal ring
   c. 3-piece penile prosthesis with submuscular reservoir placement anterior to the transversalis fascia
   d. Malleable prosthesis
   e. 3-piece penile prosthesis with counter incision for reservoir placement

2. The patient elects a 3-piece penile prosthesis with submuscular reservoir placement. During the operative procedure, the right distal corporal length is 10 cm, left distal corporal length is 10 cm, right proximal corporal length is 8 cm, and left proximal corporal length is 13 cm. What is the next best step?
   a. Insert an 18-cm cylinder length prosthesis with 5 cm of rear tip extenders on the left cylinder
   b. Place a Foley catheter and stop the procedure
   c. Insert an 18-cm cylinder length prosthesis and secure the left tubing at the corporotomy
   d. Dilate or use a Cavernotome to incise the fibrosis of the right corpora
   e. Create a mesh "windsock" in the left proximal corpora to buttress the left cylinder

3. The patient returns to you after two months reporting dissatisfaction with his glans. Specifically, he says that when penetrating his glans is bending ventrally, which causes some difficulty with sexual activity. The next step is to:
   a. Perform a glanuloplasty
   b. Replace the short cylinders with longer ones
   c. Advise him to take a phosphodiesterase-5 inhibitor to increase blood flow to glans
   d. Advise him to use a vacuum erection device to engorge the glans
   e. Remove the device to prevent erosion

4. He is continuing to complain of chronic penile pain that is exacerbated by inflation of the device 3 months postsurgery. His exam is negative for erythema, edema, fluctuance, and pump fixation. Your next step in management is:
   a. Reassurance that pain is common at this point after the procedure
   b. Refer to neurology for diabetic neuropathy
   c. Advise topical lidocaine, such as that used for premature ejaculation
   d. Refer to pain clinic
   e. Urinalysis, urine culture, serum chemistries, complete blood count, erythrocyte sedimentation rate

5. His test results are normal with the exception of a white blood cell count of 13, with 75% neutrophils and an ESR of 85 mm/h (normal 0–20). Which option is the LEAST appropriate step in management?
   a. Initiate broad-spectrum antibiotics after obtaining blood cultures
   b. Remove all components of the penile prosthesis and plan for delayed reimplant
   c. Remove all components of the penile prosthesis, perform extensive washout, and immediately reimplant prosthesis
   d. Meticulous control of blood glucose
   e. Observe

Case Study 2

A 57-year-old man presents with painful penile curvature for 2 months. He has right-sided plaque with 45-degree curvature in the middle third of his penile shaft. There is no instability or hourglass deformity.

1. Which of the following is the best treatment option?
   a. Penile plication
   b. Plaque incision and grafting
   c. Intralesional collagenase clostridium histolyticum
   d. Placement of penile prosthesis
   e. Observation

2. Which of the following is NOT an indication for penile curvature correction surgery?
   a. He dislikes the appearance of the penis
   b. He is unable to penetrate his partner
   c. His deformity is stable for at least 3 months
   d. The patient is going on a cruise with his partner next month and wants to have the deformity corrected before this
   e. He and his partner find sexual activity cumbersome or unsatisfactory

3. After 3 months of observation, the patient's deformity is unchanged and stable. When discussing penile plication, which of the following complications is LEAST likely?
   a. Erectile dysfunction
   b. Altered penile sensation
   c. Recurrence of disease
   d. Palpable sutures
   e. Hematoma

Answers

1. **c.** Seventy-three percent of positive cultures grow gram-positive bacteria, 39% grow gram-negative organisms, and 25% grow multiple organisms.
2. **c.** While it is tempting to place circumferential penile compression bandages to minimize hematoma and further chance of infection, these can be associated with penile necrosis.

CASE STUDY 1

1. **b.** A 3-piece penile prosthesis is often desired by the patient because it more closely reproduces physiologic erections. Placing the reservoir into the retropubic space through the inguinal ring is a common technique that is generally safe. However, very rarely, it is associated with serious complications, such as injury to bowel, bladder, or pelvic vascular structures. This is more likely in patients with pelvic surgery such as renal transplant. While retropubic placement of the reservoir through the inguinal ring can often be safely done, it does have the highest rate of these complications.
2. **c.** Be suspicious of any significant discrepancy in corporal length. The patient has a left crural perforation. While placing a mesh windsock is one option, it is often easier and just as effective to secure the exit tubing to the corporotomy with a suture hammock.
3. **a.** The patient has a dropping glans or supersonic transporter (SST) deformity, named after the discontinued supersonic commercial airplane which required the cockpit to droop downward in order to enhance the pilot's visualization. This issue may be remedied through a subcoronal incision and dissociation of the glans penis from the distal ends of the corporal bodies with subsequent fixation.
4. **e.** By 3 months postsurgery, his postsurgical pain should be significantly improved. You should be concerned about a late infection of the penile prosthesis.
5. **e.** The patient likely has a late infection of the penile prosthesis and should be started on broad-spectrum antibiotics. Given his insulin-dependent diabetes, glucose control, possibly with the assistance of the endocrinology team, is important. Removal with either delayed or immediate reimplantation is a viable option, but observation is not.

CASE STUDY 2

1. **e.** The patient has pain and is 3 months into his disease, and thus he is still in the active phase. All the other options are only appropriate for patients with stable disease.
2. **d.** It is inappropriate to perform a surgical correction on a patient with active disease, regardless of how eager the patient is to proceed with surgery.
3. **a.** Unlike plaque incision and grafting, plication does not alter the veno-occlusive mechanism important to maintaining erections. While the other options are all possible complications, erectile dysfunction is not expected after plication.

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53 Complications of Surgery of the Testicle, Vas Deferens, Epididymis, and Scrotum

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CHAPTER OUTLINE

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KEY POINTS

1. Scrotal surgical procedures are among the most common performed by urologists. With proper surgical planning, meticulous operative technique, and thoughtful postoperative care, the risk of complications can be minimized.
2. Blood-thinning agents should be stopped at appropriate time points preoperatively and scrotal gauze compression dressings with ice should be used postoperatively in order to decrease the risk of bleeding and scrotal hematoma formation after scrotal procedures.
3. Even if a patient has had a successful vasectomy (i.e., azoospermia or rare non-motile sperm on a fresh post-vasectomy semen analysis test), he still has a 1 in 2000 risk of future pregnancy. This complication is due to recanalization of the vas deferens.
4. The use of an operating microscope not only improves technical outcomes, but also decreases the risk of postoperative complications for surgical procedures such as microsurgical varicocelectomy and micro-TESE.
5. Scrotal ultrasonography is a noninvasive, inexpensive, and readily available imaging modality that can provide invaluable information when concerns arise regarding scrotal surgical complications.

Introduction

Surgery of the scrotum and its contents constitutes a significant proportion of outpatient and physician office-based surgeries. Despite many of the procedures being considered minor surgery, there is potential for significant complications that may be a source of tremendous pain and cost to the patient and health-care system.

Anatomy

An understanding of the anatomy of the scrotum and its contents is essential to executing safe and effective operative techniques required to treat intrascrotal pathology and minimize complications.

The scrotum is a two-layer musculocutaneous sac consisting of an outer skin layer and an inner smooth muscle

Table 53.1 Incidence of Common Scrotal Surgical Complications

Scrotal Surgical Complication	Vasectomy (%)	Varicocelectomy (%)	Sperm Extraction Procedures (%)	Vasectomy Reversal (%)	Hydrocelectomy (%)	Spermatocelectomy (%)	Orchiectomy (%)
Hydrocele	<1%	1–2% (microsurgical) 7% (nonmagnified)	<1%	<1%	1–6% (recurrence)	5–10%	N.A.
Scrotal hematoma	1–2%	1–2%	1–2%	1–2%	1–5%	1–5%	1–2%
Infection	1–2%	<1%	<1%	<1%	1–4%	1–4%	1%
Chronic pain	1–15%	<1%	<1%	<1%	<1%	<1 %	1–2%

dartos layer.[1] The dartos layer is continuous with Scarpa's fascia and is responsible for the ruggae of the scrotal wall. Dissection through the skin and dartos layers brings the surgeon to the external spermatic fascia, which is a thin connective tissue continuation of the external abdominal oblique aponeurosis. Dissection through the external spermatic fascia reveals the cremasteric fascia, which is a continuation of the aponeurosis of the internal oblique and transverse abdominal muscle. The innermost scrotal fascial layer is the internal spermatic fascia and is a continuation of the transversalis fascia. Dissection through all three intrascrotal fascial layers (external spermatic, cremasteric, and internal spermatic) reveals the tunica vaginalis. The tunica vaginalis is an enclosed peritoneal sac that is composed of a parietal tunica vaginalis that is adjacent to the internal spermatic fascia, and the visceral tunica vaginalis that is adjacent to the testicle.

The testicle surface is almost entirely surrounded by the visceral tunica vaginalis, except on its posteriolateral surface where it is connected to the epididymis.[2] The epididymis is composed of a head (caput), body (corpus), and tail (cauda) sections, which connect to the vas deferens.

Familiarity with the blood supply to the scrotum, testicle, epididymis, and vas deferens are essential in order to reduce the risk of complications during surgery. The blood supply to the scrotum is divided into the anterior and posterior scrotal arteries; the anterior arteries arise from the external pudendal branches of the femoral artery, while the posterior scrotal arteries arise from the perineal branch of the internal pudendal artery.[1] The scrotal vein drainage accompanies the arterial supply. The blood supply to the testicle is via the testicular artery (arising from the aorta), artery of the vas deferens (arising from the inferior vesical artery), and the cremasteric artery (arising from the inferior epigastric artery). The major testicular venous drainage is via the pampiniform plexus into the testicular vein, which drains into the inferior vena cava on the right and the renal vein on the left. Additional routes for venous drainage include the deferential and cremasteric veins.[3] Lymphatic drainage of the right testicle is to the paracaval, interaortocaval, and, to a lesser degree, the para-aortic nodes. The left testicle drains to the para-aortic and interaortocaval nodes.[2]

General Considerations in Scrotal Surgery

Procedures involving the scrotum and its contents are performed for a variety of indications, including malignancy, infection, infertility, contraception, pain, and cosmesis. Common, nonprocedure-specific scrotal surgical complications include hematoma, hydrocele, infection, and chronic pain (Table 53.1).

One of the most common and easily preventable complications of scrotal surgery is postoperative hematoma formation. Given the highly vascular nature of the scrotum and its contents, it is imperative that meticulous hemostasis is achieved prior to and during closure of the layers of the tunica albuginea, tunica vaginalis, fascia, dartos, and scrotal skin. Any unrecognized oozing vessel or vessel in spasm that is missed can result in considerable hematoma formation.

For most scrotal procedures, access to the scrotal contents can be obtained via a vertical median raphe incision or a transverse hemiscrotal incision. During closure of the scrotum, the forgiving nature of ruggae permits good cosmetic results even when using a running horizontal mattress closure.

Bleeding with hematoma formation is a major complication concern that can be reduced in patients taking antiplatelet and anticoagulation medications. In general, antiplatelet agents and nonsteroidal antiinflammatory agents (NSAIDs) should be stopped approximately 1 week prior to surgery, with the approval of the prescribing physician. Anticoagulant agents should also be stopped prior to scrotal surgery, with use of bridging therapy based upon clinical indication. Again, it is important to involve the prescribing physician in any changes made in the administration of these medications. Additional information regarding hematologic surgical considerations are discussed in Chapter 4, "Hematologic Complications," of this book.

Preoperative scrotal shaving should be performed at the time of surgery, as opposed to the night before, in order to reduce the risk of surgical site skin infection.[4] The removal of excess scrotal hair helps with visualization of the tissue and avoids hair entanglement with suture material. When hair removal is undertaken, the use of razors results in lower risk of infections than with clippers.[5]

Preoperative and postoperative antibiotic administration is operation dependent.

Anesthesia for scrotal procedures can be provided by general, spinal, epidural, or local anesthesia (with or without sedation). In practice, general and local anesthesia are the most commonly utilized forms of anesthesia, depending on the procedure.

Local anesthesia, administered via a spermatic cord block, is of paramount importance to master and is routinely used for numerous scrotal surgical procedures. With

a spermatic cord block, many procedures can be performed in the office setting with the patient awake. A spermatic cord block is commonly achieved using 10 mL of a 50:50 mix of 0.5% Marcaine and 1% lidocaine. The scrotal skin is initially injected with 2–3 mL of local anesthetic over the site of intended incision in order to create a wheal. Distraction techniques, such as gentle jiggling of the surrounding tissue, can be employed to help reduce the discomfort associated with the injection. The vas deferens is then isolated with the thumb and forefinger, and approximately 5 mL of local anesthetic solution is injected around it using a 25-gauge (or smaller) needle. An additional 2–3 mL of local anesthetic is injected while withdrawing the needle. Repeated advancement of the needle "in and out" during the injection should be avoided, as this approach increases the risk of vessel injury, bleeding, and scrotal hematoma formation. During closure, additional local anesthetic can be injected into the layers between the tunica vaginalis and dartos or the dartos and skin. Infiltration of the skin can be performed following skin closure.

Complications Common to Scrotal Surgery

Postoperative hematoma formation is a risk common to all types of scrotal surgery, but its incidence varies with the degree of scrotal violation. Scrotal hematomas commonly arise due to inadequate hemostasis at the time of wound closure, and they often result from inadequate visualization of a vessel in vasospasm. Nonexpanding hematomas can be managed conservatively with rest and scrotal compression using scrotal gauze dressings, ice packs, and an athletic supporter. While the diagnosis is usually self-evident, most specialists will typically order a scrotal ultrasound at the time of presentation to characterize the hematoma and quantify its size (Fig. 53.1). Hematomas typically resolve without surgical intervention over the following weeks and months, and they can be followed serially by physical examination. A hematoma that is expanding or is accompanied by evidence of infection requires surgical intervention with evacuation of the hematoma and hemostasis of the bleeding vessels. In most cases, no identifiable vessel is found during surgical exploration. A Penrose drain should be left in place postoperatively after clot evacuation to ensure drainage during the healing process. The risk of bleeding varies from 1% to 2% with vasectomy, varicocelectomy, and vasectomy reversal; to 4% in hydrocele aspiration and sclerosis; up to 5% in spermatocelectomy; and 1–5% in hydrocelectomy.[6] While bleeding following orchiectomy can occur, only 2% of men require intervention. More concerning is the risk of a retroperitoneal bleed due to cord retraction at the time of inguinal orchiectomy. While this is rarely severe bleeding, even small hematomas can mimic recurrent disease on follow-up CT. Use of preoperative CT or postoperative MRI with subtraction sequences may help in avoiding this problem.

The risk of scrotal hematoma and postoperative bleeding after scrotal surgery can be mitigated through the use of scrotal dressings that apply direct pressure to the scrotum circumferentially (Fig. 53.2). In cases of chronically inflamed or large hydrocele sacs, a trans-scrotal Penrose drain can be used to help reduce the risk of hematoma.

The risk of postoperative infection is low with most scrotal surgical procedures, and it is greatest in the setting of postoperative hematoma. Use of prophylactic antibiotics is individualized by case; they should be routinely used in hydrocele and orchiectomy, but rarely used, for example, in vasectomy. In high-risk patients, such as the immunocompromised individual or those with diabetes mellitus, antibiotics can be used at the surgeon's discretion. Infections should be treated aggressively to prevent Fournier's gangrene.

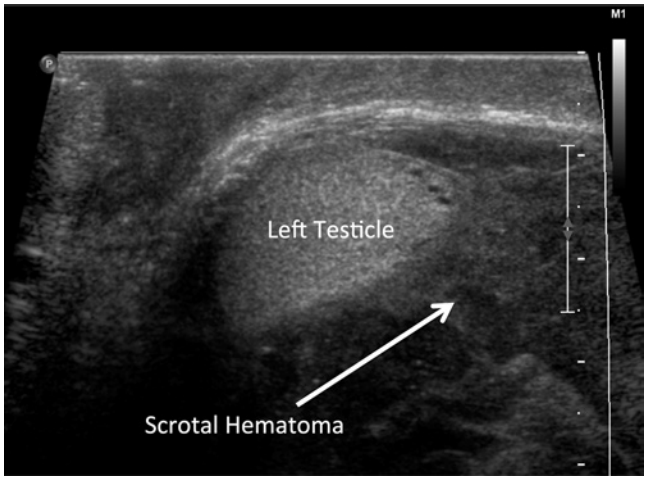


Figure 53.1 Ultrasound image revealing a left hemiscrotal hematoma surrounding the left testicle.



Figure 53.2 A scrotal supportive pressure dressing comprised of copious amounts of gauze that is form-fitted around the scrotum and secured in place by an athletic supporter. This pressure dressing minimizes the risk of postoperative bleeding and scrotal hematoma formation.

Vasectomy

Vasectomy is the only form of permanent male contraception, and this procedure is performed on more than 500,000 men annually in the United States.[6] Despite being a fast, low risk, and cost-effective form of contraception, it still remains an underutilized form of permanent contraception compared to tubal ligation in women. In couples in the United States between the ages of 15 and 45, 17% of female partners elected to undergo tubal ligation, compared to 6% relying on the male partner to undergo a vasectomy.[7,8] Despite the increased cost, procedure time, and risk of complications associated with tubal ligation, it remains the more utilized permanent sterilization procedure due to many factors, including cultural issues and a limited awareness of vasectomy.[8]

A pre-vasectomy consultation is essential in preparing the patient and the physician for the procedure and informing the patient about possible complications. Some states mandate that the consultation occur at least 1 week (in some states such as New York, at least 1 month) prior to vasectomy in order to give the patient time to consider treatment alternatives. A full history and physical examination is required, as well as counseling to assess his interest in future paternity, his knowledge and expectations about the procedure, and postoperative contraception requirements. Studies have shown that 10–19% of males harbor a desire to father children post vasectomy, with approximately 6% of men undergoing a vasectomy reversal within a 5-year period afterward.[9–11] This emphasizes the importance of informing the patient about the permanency of a vasectomy during the preoperative counseling. While "post-vasectomy regret" is not commonly regarded as a procedural complication, proper counseling might avert a procedure in a patient who is uncertain about his actual desire for future paternity.

An examination of the vas deferens in the pre-vasectomy consultation is critical to ensure the anatomy is conducive to performing the procedure under local anesthesia in the office setting. Patients with challenging anatomy due to morbid obesity, a high riding testicle, a spermatic cord lipoma, or a hypoplastic scrotum might be better served by having their procedure performed under intravenous sedation or general anesthesia. This approach can help optimize patient comfort and technical feasibility of the procedure.

VASECTOMY PROCEDURE TECHNIQUES

Vasectomy is typically performed in the physician's office or in the outpatient surgery center, usually under local anesthesia. The patient is placed in the supine position in a warm room to permit scrotal relaxation. Prophylactic antibiotics are not required (although some high-volume surgeons do administer them). For a right-handed surgeon, the right vas deferens is isolated while standing on the right side of the patient using the thumb (anteriorly) and middle finger and index fingers (posteriorly). The mid-to-upper scrotal vas deferens should be isolated high in the scrotum, and then a spermatic cord block is placed using the previously mentioned local anesthetic solution. As described in the American Urological Association Vasectomy Guidelines, the procedure can be performed using a "minimally invasive vasectomy" (MIV) technique to isolate the vas deferens, such as the "no-scalpel vasectomy" (NSV) technique. The NSV approach has shorter procedure times and less risk of infection, bleeding, and hematoma formation.[12]

No-scalpel vasectomy is performed with a sharp curved hemostat instead of a scalpel. After the spermatic cord block is placed, dissection through the skin is accomplished using a single arm of the sharp curved hemostat followed by dilating the skin with the hemostat. Continued dissection to the vas deferens through the dartos and peri-vasal sheath is accomplished with the hemostat. The vas deferens is secured and brought out through the incision with a vasal clamp. Once a 1.5–2 cm segment of vas deferens has been dissected out of the sheath, a 1-cm segment of vas deferens is sharply excised. This segment does not need to be sent for pathologic confirmation under the current AUA guidelines. The vas deferens is doubly ligated with either hemoclips or 2-0 silk ties. Vasal occlusion of the vasal ends is achieved via electrocautery to the vasal edges and lumen. Fascial interposition is achieved by securing spermatic fascia between the testicular and abdominal vasal ends. This combination of ligation, cautery, and fascial interposition has been shown to reduce vasectomy failure rates.[13] There is no need for skin suturing due to contraction of the wound to 2 mm in size after cautery.[14]

After vasectomy, the following steps can be taken to promote healing and minimize the risk of complications. Scrotal ice packs, scrotal gauze dressings, and a compressive scrotal supporter are applied for approximately 24 hours to reduce pain as well as the risk of swelling and hematoma. Exercise and strenuous physical activity should be limited for 5–7 days, although driving can resume after 1–2 days if the patient is not taking narcotics. Patients should refrain from ejaculation for 7 days after the vasectomy. Analgesia with scheduled acetaminophen is usually sufficient for postoperative pain management. Per the AUA Vasectomy Guidelines, it is critical that patients use an alternate form of contraception until the mandatory post vasectomy semen analysis (PVSA) test reveals one test with azoospermia at any point post vasectomy, or rare nonmotile sperm (<100,000/mL) in one well-mixed, uncentrifuged fresh post-vasectomy semen specimen. In the past, the recommendation had been for two negative PVSA.[15] Compliance with the requirement for a negative semen analysis is low, with only 50% of patients supplying one or more negative semen analyses in contemporary studies despite verbal and written instructions provided to the patients.[16] The time period is variable for men to achieve an azoospermic PVSA and typically requires at least 20 ejaculations.[17] Recent 2016 British Best Practice guidelines recommend the first PVSA should occur at a minimum of 12 weeks and be analyzed within 4 hours.[18] PVSA performed >12 weeks post vasectomy have a 93% likelihood of having a negative analysis.[15,19] It is important to inform patients that even in the setting of an azoospermic PVSA, there still remains a risk of recanalization and, with that, a 1 in 2000 risk of future pregnancy.[20]

MANAGEMENT OF SPECIFIC COMPLICATIONS

Common complications associated with vasectomy procedures are listed in Table 53.1.

Testicular artery injury/ligation can occur during the course of the vasectomy procedure. In most instances, collateral flow from the cremasteric artery and deferential artery will sustain the testicle. Care should be taken, however, to avoid testicular artery injury or ligation, because these collateral vascular structures might not be well developed in all men. Furthermore, men who have undergone a prior herniorrhaphy, orchidopexy with Fowler-Stephens approach, or varicocelectomy might have had either intentional or inadvertent ligation of the testicular, deferential, and/or cremasteric arterial vessels in the course of those procedures. For men with such prior surgical history, extreme care should be taken to avoid an arterial injury during vasectomy that could lead to ischemic loss of the testicle. There are no substantial published data on testicular artery repair in the setting of vascular injury during vasectomy.

Vasectomy failure is defined by the presence of motile sperm on PVSA and can be divided into early or late. *Early failure* occurs in 0.3–13% of vasectomies and results from early recanalization or technical error with failure to divide the vas deferens.[21] If motile sperm are found on the first PVSA at 8–16 weeks, management includes repeat semen analysis every 4–6 weeks because spontaneous occlusion of early recanalization can occur in over 50% of men, resulting in "delayed vasectomy success."[21] If motile sperm persist >6 months post vasectomy, a repeat vasectomy is required as vasectomy failure has occurred.

"Late failure" This complication occurs due to recanalization of the vas deferens months or even years after sterilization has been performed. The risk of pregnancy is 1 in 2000 for men who achieve azoospermia or have rare nonmotile sperm in their postvasectomy semen analysis.

Sperm granulomas occur in less than 5% of vasectomized men.[20] They result from inflammation triggered by leakage of sperm from the testicular vasal end, and, although they can occur following any type of vasectomy, they are most commonly associated with the open testicular end approach. Sperm granulomas may be palpable and symptomatic, but pain is usually temporary. In rare patients, the associated discomfort may become chronic in nature. For patients with symptomatic sperm granuloma's, conservative management with oral NSAIDs is usually effective at alleviating inflammation and tenderness. If, however, there is persistent pain or continued granuloma enlargement, excision of the sperm granuloma can be considered.

Post vasectomy pain syndrome (PVPS) has been reported in up to 15% of patients, but only 1% of these men report an impact on their quality of life.[24] Among men with PVPS, only about 1% choose to undergo additional surgical intervention.[25] The pain is most commonly caused by chronic epididymal congestion with or without inflammation (epididymitis), but other causes include nerve entrapment, neuroma, or sperm granuloma formation. Surgical interventions available include vasectomy reversal, epididymectomy, spermatic cord denervation, sperm granuloma excision, and, if all else fails, orchiectomy. Vasectomy reversal in carefully selected patients with PVPS has been shown to result in an 82% chance of pain improvement, with one-third of patients reporting complete resolution of their pain.[26,27] Epididymectomy is associated with a 93% success rate in reducing pain in men with PVPS, and close to 25% of men undergoing this procedure report resolution of all pain.[28] Spermatic cord denervation is being increasingly used to treat chronic scrotal pain, including PVPS. In the setting of PVPS, 76% of patients who underwent spermatic cord denervation were found to have resolution of their pain, and the remaining 24% experienced an improvement in their discomfort.[29]

Fistula formation is a rare complication that can occur in the form of a vasovenous or vasoarterial fistula.[30,31] Vasovenous fistula may present with an initial postoperative hematoma that progresses over weeks or months to hematuria. The mechanism is believed to be fistula formation due to chronic inflammation at the site of clip or suture placement. Cystoscopy may demonstrate blood emanating from the ipsilateral ejaculatory duct. Treatment consists of scrotal exploration, ligation, and excision of the fistula. Vasoarterial fistulas are also rare but may occur when a suture perforates an artery resulting in a vasoarterial connection. Scrotal exploration is indicated in these patients, and attempts are made to spare the arterial structure if possible.

LONG-TERM CONSIDERATIONS

Some controversy has arisen over the years regarding the possible association between vasectomy and the risk of developing aggressive *prostate cancer*. However, evidence to date suggests that there is no correlation between vasectomy and the future risk of prostate cancer.[15,32] Likewise, a concern about the association between vasectomy and testicular cancer arose following small case control studies in the 1980s.[33,34] However, a subsequent large-scale population analysis involving close to 74,000 vasectomized men found no increased risk of either testicular cancer or acceleration of preexisting testicular carcinoma in situ.[35]

Initial concerns about an association between vasectomy and an increased risk of *coronary heart disease* (CHD) arose following studies on vasectomized monkeys, where advanced atherosclerosis was identified.[36,37] The authors hypothesized that post vasectomy anti-sperm antibody immune complexes may have contributed to atherosclerosis. The overwhelming body of evidence in humans has found no association between vasectomy and future risk of CHD, with one study showing that men who underwent vasectomy actually had a lower risk of CHD[15,38,39]

Primary progressive aphasia (PPA) is a rare variant of frontotemporal dementia that was found in a small case control study to be associated with a prior history of vasectomy and anti-sperm antibodies.[40] The association between anti-sperm antibodies and dementia has not been further established in larger studies nor has there been any association of anti-sperm antibodies with severe immune-related diseases.[41,42]

Vasectomy was also not found to be associated with an increased overall *mortality* following a retrospective study comparing 14,000 vasectomized and nonvasectomized men.[43]

The AUA Guidelines on Vasectomy state that the above issues need not be discussed with patients given the lack of evidence supporting an association between them and vasectomy.

Varicocelectomy

A varicocele is an abnormal dilation of the pampiniform venous plexus within the spermatic cord. Varicoceles represent the most common surgically correctable form of male infertility with approximately 37,000 varicocelectomies performed annually in the United States.[44] An estimated 15% of the general male population have clinically evident varicoceles. This prevalence increases to 35% of males with primary infertility and 80% of males with secondary infertility.[45–47] Varicoceles are associated with reduced semen parameters (specifically sperm concentration and motility), hypogonadism, and testicular atrophy.[48,49] Left-sided and bilateral varicoceles account for the majority of cases, and solitary right-sided varicoceles should prompt retroperitoneal imaging to rule out pathologic processes obstructing the right gonadal vein. Varicoceles are most commonly asymptomatic, but they may present with pain or a scrotal mass.

INDICATIONS FOR REPAIR

Indications for intervention include the presence of a clinically palpable varicocele with:

1. Abnormal semen parameters in an infertile male whose partner has either no female factor issues or else a correctable female factor issue
2. Abnormal semen parameters in a male not currently trying for a pregnancy but who is interested in repair
3. Ipsilateral testicular volume discrepancy
4. Varicocele symptoms (reproducible pain that is elicited when the patient is erect or sitting) that are typically relieved when the patient is in the supine position.

Varicocelectomies should *not* be performed on asymptomatic men with normal semen parameters or in cases of subclinical (nonpalpable) varicoceles.

VARICOCELE REPAIR TECHNIQUES

Interventions include surgical correction and percutaneous radiologic embolization. Surgical options include high ligation via an open retroperitoneal or laparoscopic approach, or low ligation via inguinal and subinguinal approaches.

The open retroperitoneal approach was initially described by Palomo in 1948 and involves isolation of the internal spermatic vessels above the internal inguinal ring via an incision made 3–4 cm medial to the anterior superior iliac spine.[50] Dissection proceeds down through Campers and Scarpa's fascia, continuing through the external and internal oblique (with care to avoid to the ilioinguinal nerve) and transversus abdominis muscles. Once in the retroperitoneum, the vessels can be identified, ligated, and divided. The retroperitoneal technique has a high recurrence rate (up to 15%), as it fails to ligate the external spermatic vessels. The hydrocele formation rate is also higher than with other approaches, as the lymphatics vessels are ligated en bloc with the surrounding vessels. Testicular atrophy is uncommon due to collateral arterial supply via the external spermatic and vasal arteries. Once the internal spermatic vessels are ligated and divided, each layer of the abdominal wall is closed. The advantage of the retroperitoneal approach is its speed and need to typically ligate only one to three veins.

The laparoscopic approach has similar outcomes to the open retroperitoneal approach, as it targets ligation of the internal spermatic vessels above the internal ring. Although artery-preserving laparoscopic techniques have been described, the majority of laparoscopic procedures fail to preserve arteries or lymphatics. As a result, the recurrence and hydrocele rates are similar to the open retroperitoneal approaches. Given that this approach is intraperitoneal, the laparoscopic approach also runs the risk of injury to viscera and vasculature.

The microsurgical open approach has largely replaced the open nonmagnified approach, as magnification optimizes identification and isolation of the veins, arteries, and lymphatics. Magnification assists in reducing the risk of recurrence, testicular atrophy, and hydrocele formation.

The microsurgical inguinal approach is performed via a 3- to 4-cm incision above the external ring, with dissection down to and through the external abdominal oblique. The spermatic cord is identified and brought to the skin surface. The operating microscope is then maneuvered into the field to assist in visualization, identification, and preservation of arteries and lymphatic vessels. Additionally, the operating microscope assists in identification and ligation of the external and internal spermatic veins. The inguinal approach is not fascia sparing, which might increase the postoperative recovery time and pain in some patients over the subinguinal technique.

The microsurgical subinguinal approach is a fascia-sparing procedure that avoids dissection through the external aponeurosis. A 3-cm incision is made over the external ring, and dissection proceeds down through Campers and Scarpa's fascia until the spermatic cord is identified (Fig. 53.3A). The cord is then isolated and brought out through the incision site. Some surgeons will deliver the entire testicle into the field in order to identify, ligate, and divide the gubernacular veins.[51] The external and internal spermatic fascia of the spermatic cord are opened, revealing the internal spermatic veins, testicular artery, lymphatic vessels, and vas deferens. Anatomic studies have shown that the more distal subinguinal approach is slightly more time consuming due to the increased number of veins that require ligation, as well as the increased number of arterial branches that need to be avoided. Despite this, the subinguinal approach has become the preferred choice for most subspecialists due to the reduced postoperative pain levels and recovery times, as well as the lowest rates of recurrence, hydrocele formation, and testicular atrophy.[52,53] A microsurgical Doppler unit can be used intraoperatively to help identify and preserve the testicular artery. This piece of equipment is extremely important in minimizing the risk of testicular artery injury, inadvertent testicular artery ligation, and potential loss of the testicle (Fig. 53.3B).

MANAGEMENT OF SPECIFIC COMPLICATIONS

Common complications associated with varicocelectomy procedures are listed in Table 53.1.

While varicocelectomy is not truly an intrascrotal procedure, many of the same complications that can occur as a

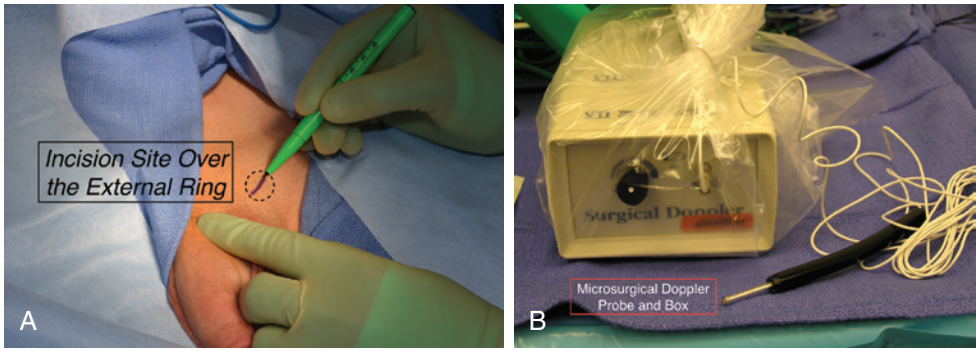


Figure 53.3 A, Intraoperative photograph depicting a left subinguinal incision site marked over the left external ring. The subinguinal approach is used in microsurgical subinguinal varicocelectomy, and this technique has lower recurrence rates and lower overall complication rates than do laparoscopic, retroperitoneal, and inguinal approaches. B, The microvascular Doppler ultrasound (20 megahertz) unit facilitates intraoperative identification and preservation of arterial vascular structures during microsurgical varicocelectomy.

result of intrascrotal surgery can also arise during and after varicocelectomy procedures (Table 53.1). Several complications are unique to varicocelectomy, however, and these vary depending on the surgical approach used.

The fascia-sparing subinguinal approach has the lowest level of associated postoperative pain and the fastest associated time for return to work, with a median time of 8 days.[54] The laparoscopic approach has a similarly rapid recovery period and a relatively low level of postoperative pain. The open, muscle splitting inguinal and retroperitoneal procedures have the greatest relative postoperative pain and time to return to work outcomes.

Ilioinguinal nerve injury can result in paresthesia or pain over the scrotum and medial thigh. These symptoms usually resolve over a period of weeks to months with conservative management. Severe pain may develop due to *ilioinguinal nerve entrapment* following an inguinal approach. In patients with persistent, intractable pain who have relief following a nerve block, a neurectomy or microsurgical cord denervation procedure have both been shown to improve pain control.[55,56] *Varicocele persistence or recurrence* can occur when there is failure to ligate venous collaterals in the internal and external spermatic venous system. Rates of recurrence are lowest with the microsurgical subinguinal approaches (0–2.6%) and higher in the open nonmagnified inguinal approach (5–17%).[51,54,57] The open retroperitoneal and laparoscopic approaches have comparably high recurrence rates of 5–15%. This high rate is due to ligation of only the internal spermatic vein(s) at the level of the internal ring, and the untreated external spermatic veins can contribute to persistence or recurrence.

It is common for the ligated varicocele to remain palpable for months following the procedure. In the setting of suspected varicocele recurrence/persistence, a scrotal ultrasound demonstrating dilated veins with reversal of flow on Valsalva maneuver confirms the diagnosis. If there is evidence of recurrence/persistence, then treatment options include reoperation via a microsurgical subinguinal/inguinal approach or radiographic embolization. If reoperation with a microsurgical approach is pursued, delivery of the testicle with gubernacular vessel ligation can be considered to reduce the likelihood of ongoing recurrence/persistence.

Hydrocele formation following varicocelectomy results from deliberate or inadvertent ligation of the lymphatic vessels.[58] Microsurgical approaches carry the lowest risk of hydrocele formation (0–0.69%) due to enhanced visualization of lymphatic vessels, which facilitates their preservation. Hydrocele risks are significantly higher for the open nonmicrosurgical inguinal (3–30%), retroperitoneal (15–25%), and laparoscopic approaches (5–15%) when compared to lower subinguinal approaches.[51,54,57] Asymptomatic small hydroceles can be managed conservatively while large symptomatic hydroceles might require intervention, based on degree of patient bother. Postoperative hydrocele formation will require a hydrocelectomy in 10–15% of patients.[59]

Interestingly, ligation of the lymphatic vessels can cause in rare cases a dramatic increase in testicular size, which is due to biopsy-proven interstitial testicular edema.[60] This edema-induced *pseudohypertrophy* is associated with impaired spermatogenesis. Pseudohypertrophy, particularly in adolescent males, should be suspected in the setting of rapid testicular enlargement in the 6 weeks–6 months following a varicocelectomy, as physiologic "catch up growth" takes considerably longer in adolescents with varicocele-induced testicular size discrepancy.

Testicular atrophy results from injury to the testicular arterial supply (testicular artery, external spermatic artery, and vasal artery) and is uncommon, occurring in <1% of all approaches.[52,61] The lowest rates of arterial ligation occur with the microsurgical approaches due to superior visualization, identification, and preservation of the arteries. During the open retroperitoneal and the laparoscopic approaches, the internal spermatic artery is commonly ligated along with the vein. However, testicular perfusion is maintained via the collateral vasal artery and the external spermatic artery blood supplies.[62] Chan et al. reported on testicular artery microsurgical repair after accidental ligation during varicocelectomy. These authors repaired the injured vessels in two patients, although the deleterious impact of each event might have been mitigated because each patient also had an intact vasal artery and one additional intact testicular artery. In order to mitigate the risk of vascular injury in men with a solitary testicle or a history of previous inguinal surgery, microsurgical techniques are advisable.

Superficial dorsal penile vein thrombosis is a rare complication that has been reported to occur in 2.1% of subinguinal varicocelectomies.[63] This condition can present 2–3 weeks

after varicocelectomy, after resumption of sexual activity, with pain and a thickened cord-like induration on the dorsal aspect of the penis. This condition typically arises due to injury of the superficial dorsal penile vein as it traverses the groin to drain into the left femoral or great saphenous vein. The injury likely initiates thrombus formation with retrograde propagation, causing the pain and induration on the dorsum of the penis. The management is conservative measures with NSAIDs and abstinence from sexual activity until resolution occurs after 3–6 weeks.

Sperm Extraction Procedures

Substantial advancements have been made in the field of reproductive medicine over the past 25 years, and these have given rise to improved paternity rates via assisted reproductive technologies such as IVF/ICSI. For many patients with azoospermia, surgical sperm retrieval is required in order to extract sperm for use in assisted reproduction. This approach has expanded the role of microsurgical techniques, which have largely replaced macroscopic approaches for many sperm extraction procedures.

SPERM EXTRACTION PROCEDURE TECHNIQUES

Sperm retrieval procedures are performed in both cases of obstructive and nonobstructive azoospermia. Obstructive azoospermia occurs in the setting of congenital bilateral absence of the vas deferens, idiopathic and acquired epididymal obstruction, ejaculatory duct obstruction, vasectomy, and failed vasectomy reversal. In the case of obstructive azoospermia, spermatogenesis is intact, which permits sperm retrieval via either microsurgical epididymal sperm aspiration (MESA) or percutaneous epididymal sperm aspiration (PESA) techniques. In the event that sperm are not retrieved via epididymal aspiration, testicular sperm extraction (TESE) or microdissection testicular sperm extraction (Micro-TESE) can be attempted.

In patients with nonobstructive azoospermia, the absence of sperm in the ejaculate is not necessarily synonymous with complete absence of sperm in the testicle. In greater than 50% of patients with nonobstructive azoospermia, viable sperm will be found using the micro-TESE technique.[64] Micro-TESE has emerged as the gold standard for testicular sperm retrieval in nonobstructive azoospermia due to higher sperm retrieval rates (SRRs) and a lower risk of complications.[65–67] In certain instances of nonobstructive azoospermia, such as genetic mutations of the entire AZFa and AZFb regions of the Y chromosome, there is no benefit to attempting sperm retrieval due to complete absence of spermatogenesis.[68] The main surgical options for nonobstructive azoospermia are Micro-TESE, TESE, percutaneous testicular biopsy (PTB), and fine needle aspiration (FNA).

Micro-TESE utilizes an operating microscope with 15–25 × magnification to inspect the seminiferous tubules for evidence of spermatogenesis and usually involves a midtesticular horizontal incision. The testicle is delivered into the field and the tunica vaginalis is incised exposing the testicle. The microscope is brought into the field to optimize visualization prior to making the single midtesticular horizontal incision. Microsurgical magnification assists in preserving the subtunical vessels, minimizing the risk of bleeding, identifying the larger, more opaque seminiferous tubules that are more commonly associated with spermatogenesis (Fig. 53.4A). Seminiferous tubules are excised with a curved iris scissors, and a wet prep slide is prepared to assess for the presence of sperm using phase contrast microscopy at high power (× 400) magnification. Bipolar electrocautery is used for hemostasis. Meticulous attention to hemostasis during closure is essential in order to minimize the risk of postoperative hematoma formation (Fig. 53.4B).

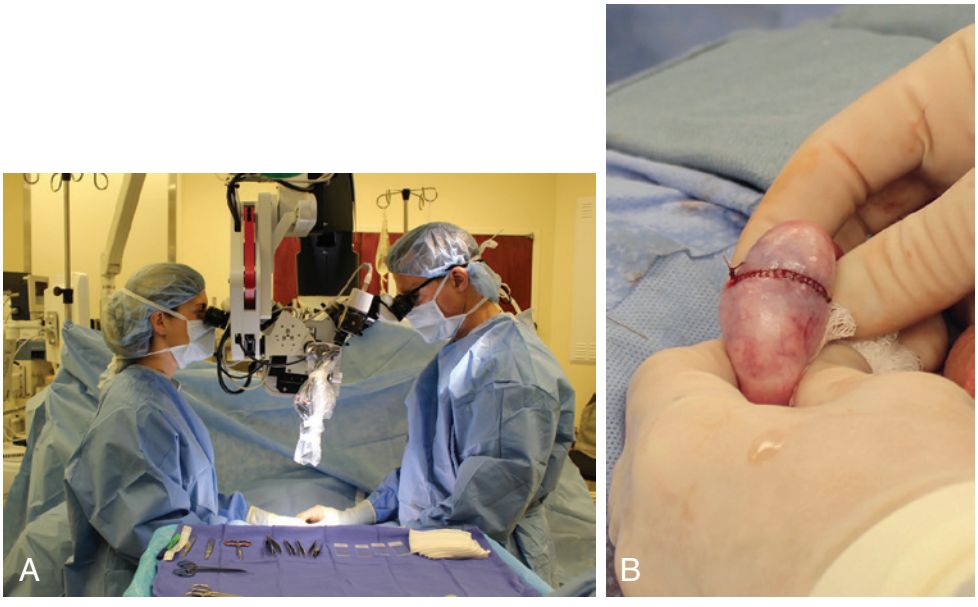


Figure 53.4 A,The operating microscope provides up to 25X magnification and guides seminiferous tubule dissection and sampling during the Micro-TESE procedure. The operating microscope also enables identification and preservation of testicular vascular structures during the procedure, thus minimizing postoperative bleeding risk. B, Meticulous attention to hemostasis during testicular and scrotal closure is essential in order to minimize the risk of postoperative hematoma formation.

Percutaneous biopsy and FNA are less commonly used as they are "blind procedures" and have higher complication rates and lower SRRs. PTB and FNA are both of relatively short duration and can be done under local anesthesia. After placement of a spermatic cord block, a small weal of anesthesia is injected at the site of a tiny scrotal skin incision. With the FNA approach, a tiny incision is made, a 23-gauge needle is attached to a 20-mL syringe that is passed into the testicle, and negative pressure is generated. Using back and forth movements, fluid and seminiferous tubules are aspirated. A percutaneous biopsy involves the use of a 14-gauge or 16-gauge automatic biopsy gun, which is advanced through the scrotal incision and through the tunica albuginea. The biopsy gun is then triggered, and it collects the testicular biopsy core. The core is then removed, placed in solution, and inspected using microscopy. With both the PTB and FNA approaches, a single suture is placed and scrotal pressure dressing and ice are applied for 24 hours.

Microdissection epididymal sperm aspiration (MESA) and percutaneous epididymal sperm aspiration (PESA) techniques can be used in cases of obstructive azoospermia to obtain sperm from the epididymis. PESA, although relatively quick and cost effective, has a lower SRR and has a greater risk of vascular injury than does MESA. PESA involves percutaneous aspiration of epididymal fluid from the dilated epididymal caput using a 23-gauge or 25-gauge butterfly needle. MESA, however, involves open exposure of the epididymis to facilitate epididymal fluid aspiration under microsurgical vision.

Overall, nonobstructive azoospermia SRRs for FNA, TESE/multiple open biopsies, and Micro-TESE are 11–47%, 17–45%, and 42–62%, respectively.[67,69–73] Success for PESA and MESA in obstructive azoospermia is up to 92% and 100%, respectively.[74]

MANAGEMENT OF SPECIFIC COMPLICATIONS

Common complications associated with sperm extraction procedures are listed in Table 53.1.

The risk of clinical *hematoma* with Micro-TESE is low. The risk of subclinical hematoma detected on testicular ultrasound is 12% following Micro-TESE and 51% after TESE at 1 month.[67] Chronic changes are not typically seen following Micro-TESE, but are seen in up to 23% of patients who underwent TESE. The significance of these subclinical findings on ultrasound is yet to be determined. Although hematoma is uncommon, scrotal ecchymosis is common and can be limited by scrotal support and ice following the procedures.

Decreased testicular volume occurs in only 2.5% of patients undergoing Micro-TESE but up to 10% of patients undergoing TESE.[67] In part, this is related to a lower volume of tissue extracted during Micro-TESE than during TESE.[67] This impact of the procedure on testicular size may in part be responsible for the associated 20% decrease in serum testosterone at 3–6 months post Micro-TESE and TESE. Testosterone levels usually return to 95% of baseline at 18 months in Micro-TESE patients, but only to 85% of preoperative baseline in TESE patients.[75] There has been one report of a patient who underwent a TESE and became hypogonadal secondary to bilateral testicular ischemia and atrophy, ultimately requiring exogenous testosterone therapy.[67] TESA has not been shown to be associated with a decrease in testicular volume or serum testosterone.

Postoperative inflammation can result in *testicular fibrosis* and *scar formation*, which can be detected on scrotal ultrasound. Some studies have shown fibrosis following TESE in up to 23–30% of patients compared to 0–3.3% in patients after Micro-TESE.[65,67]

Vasectomy Reversal (Vasovasostomy and Vasoepididymostomy)

Approximately 6% of the 500,000 men that undergo a vasectomy annually will eventually elect to have a vasectomy reversal requiring either a vasovasostomy (VV) or vasoepididymostomy (VE).[76] Vasectomy reversal remains the most common indication for VV or VE but others include epididymal obstruction as a result of congenital bilateral epididymal agenesis, epididymitis, and trauma or iatrogenic injury.[77] A VV may also need to be performed to treat post vasectomy pain syndrome, following traumatic injury to the vas deferens, or after iatrogenic injury sustained during an inguinal hernia repair.

The evolution of VE and VV from their macrosurgical origins (in 1902 and 1911, respectively) to current-day microsurgical procedures was accompanied by improvement from relatively low patency rates to rates of approximately 68% and 95%, respectively. These advances have come as a result of technologic and procedural innovation, an understanding of the implications of vasal fluid quality and intraoperative decision making, and the impact of female partner factors.[77–80] Technical optimization with the microsurgical approach requires regular exposure to microsurgery in order to remain technically proficient. This has resulted in a subspecialized shift of the procedures to fellowship-trained urologists, especially when VE is performed.[81]

Patients undergoing a vasectomy reversal procedure should be informed that secondary epididymal obstruction can occur following vasectomy. For such patients, microsurgical reconstruction woud require a VE, which has a lower patency rate than VV. Epididymal obstruction after vasectomy is caused by intraluminal backpressure that leads to epididymal tubule "blowout" (rupture) with subsequent scarring and stenosis.[82] Post vasectomy epididymal obstruction is most commonly associated with an interval of >15 years since vasectomy, although it can occur at any time interval after the vasectomy. In 62% of patients who were >15 years post vasectomy, a unilateral or bilateral VE was required due to concurrent epididymal obstruction.[83] Despite having a lower patency than VV, VE still has reported patency rates of 65–80%.[84] Patients should be informed that after patency is confirmed, it takes on average 12 months to achieve a pregnancy.[84]

VASECTOMY REVERSAL PROCEDURE TECHNIQUES

VVs and VEs are ideally done under general anesthesia, although they can be performed under regional or local

anesthetic. The patient is placed in the supine position and prepped following shaving. The incision for a VV or VE can be made through a midline raphe incision or more commonly via a high scrotal vertical incision. Dissection is continued down to the vas deferens to the site of the vasectomy. A healthy segment of the vas deferens is identified 1 cm from the vasectomy site. Mobilization of the vas deferens is essential in order to perform a tension-free anastomosis, and this requires dissection of the surrounding tissue with preservation of the vasal blood supply in order to avoid subsequent anastomotic stricture.

Fluid from the testicular vas deferens is assessed macroscopically for the color and consistency, and microscopically for the presence or absence of whole sperm or sperm parts. If no vasal fluid is seen, VE should be performed. If the fluid found is clear or opalescent with sperm or sperm parts, then a VV can be performed.[84,85] A VE should be performed if thick, toothpaste-like fluid without sperm returns, as this is consistent with epididymal obstruction. The abdominal vas deferens is then assessed for patency by gentle irrigation with 5 mL of normal saline through a 24-gauge angiocatheter. Once patency is confirmed the anastomosis of the two ends of the vas deferens can occur.

Anastomosis is most commonly done via a two-layer approach, although similar patency rates have been found with a modified single-layer anastomosis.[86] The two-layer anastomosis uses 10-0 nylon sutures to reapproximate the mucosa, and 9-0 nylon to reapproximate the muscularis. The modified single-layer closure utilizes 9-0 nylon. Whichever technique is used, the anastomosis should be leak proof and tension free.

If a VE is performed, the tunica vaginalis is opened and the testicle delivered. The abdominal vas deferens is mobilized sufficiently to ensure adequate length to the epididymis. Given the importance of the epididymis in sperm maturation, anastomosis is performed as distally as possible.[87] A VE is typically performed via a traditional end-to-side anastomosis or an intussuscepted end-to-side anastomosis.

Postoperatively patients are typically discharged home the day of surgery with scrotal support and ice packs for 24–48 hours. Return to light work duties can occur after 5–7 days postoperatively, but the patient should refrain from substantial physical exertion and sexual activity for at least 2 weeks in order to minimize the risks of increased inflammation, anastomotic leak, and stricture. Semen analysis is typically performed at 6–8 weeks and then every 2–3 months until motile sperm are detected or pregnancy occurs.

Postoperative patency may not be evident on semen analysis testing for up to 12 months following a VV and up to 24 months following a VE. Overall patency and pregnancy rates for VV are 86–99% and 46–92.5%, respectively.[80,84,88] VE is associated with lower patency and pregnancy rates, 65–80% and 30–40%, respectively.[80,89]

MANAGEMENT OF SPECIFIC COMPLICATIONS

Common complications associated with vasectomy reversal procedures are listed in Table 53.1.

Postoperative *infection*, *hematoma*, and *testicular atrophy* are rare, and preoperative, prophylactic antibiotics are routinely given to reduce the risk of infection. Postoperative scrotal edema and orchalgia can occur but usually resolve spontaneously.[90]

Vasovasostomy *primary anastomotic failure* is suspected if there is an absence of sperm on SA after 12 months. Early failure may result from an anastomotic leak causing inflammation and luminal stenosis. Leaks can result from inadequate approximation of the vasal ends, puncture of the vasal lumen, or misalignment of the anastomosis.[91] In rare circumstances leaks can arise due to infection. Unrecognized epididymal obstruction following previous vasectomy can also be a cause of VV failure. In the setting of early failure, patients can undergo "re-do" VV or IVF/ICSI. Repeat reversals have reasonable patency rates of 78% and pregnancy rates of 44%.[92,93] A repeat reversal has also been shown to be 2.4 times less expensive than undergoing IVF /ICSI.[94]

Delayed anastomotic failure occurs in up to 12% of patients and is defined by sperm seen on postoperative SA that subsequently decreases with time. This usually occurs 9 months postoperatively.[80,95,96] This secondary azoospermia/oligospermia is caused by vasal scarring and can be treated with NSAIDs or steroids to reduce the inflammatory process. Patients should also be offered cryopreservation of sperm in the event azoospermia does ultimately occur. If secondary azoospermia does indeed occur, a "redo" VV or a VE can be undertaken.

Vasoepididymostomy has lower success rates due not only to the technical difficulty associated with the procedure, but also due to the role the epididymis plays in imparting sperm maturation and sperm motility. The closer to the caput of the epididymis the VE anastomosis is placed, the less likely motile sperm will be found on SA.[87] There is also a risk of *ischemic epididymal fibrosis* and/or *testicular atrophy* with VE, but these are rare events and usually occur in the setting of multiple reconstructions. For patients with a failed VE (absence of sperm after 15–24 months), a repeat VE or IVF/ICSI are both options. Recently pre- and postoperative nomograms have been created to help counsel patients on the likelihood of requiring a VV or VE preoperatively and the likelihood of success postoperatively.[97]

Hydrocelectomy

A hydrocele is an abnormal collection of fluid between the testicle and the tunica vaginalis. Hydroceles are believed to occur when fluid resorption, which typically occurs in the space between the visceral and parietal layers of tunica vaginalis, does not occur normally. Hydroceles affect 1% of the male population, predominantly occurring in men over the age of 40.[98] Hydroceles are divided into "communicating" and "noncommunicating" categories, based on whether or not they are in continuity with the peritoneal space. Hydroceles are further divided into primary (idiopathic) or secondary (infection, malignancy, trauma, lymphatic obstruction, iatrogenic) types and may be septated or nonseptated.

Following a history and physical examination (including transillumination of the scrotum), a scrotal ultrasound is typically performed in order to assess for any underlying testicular pathology. In cases of a moderate or large hydrocele where an optimal testicular examination is

impeded by the intrascrotal fluid volume, the scrotal ultrasound is essential in order to rule out a testicular tumor. In the setting of a reactive hydrocele secondary to testicular tumor, an inguinal approach is of course used, rather than the more commonly used trans-scrotal hydrocelectomy approach used in cases of benign etiology. Secondary hydroceles caused by infection or trauma can often be managed conservatively, as many of these will resolve spontaneously with time and will not require surgical intervention.

HYDROCELE TREATMENT OPTION TECHNIQUES

Aspiration and Sclerotherapy

Aspiration and sclerotherapy of a hydrocele has a higher persistence/recurrence rate when compared to hydrocelectomy, and aspiration and sclerotherapy is an alternative reserved only for poor surgical candidates as this technique can be performed under local anesthesia. Sclerotherapy is used in conjunction with aspiration to induce an inflammatory reaction, producing fibrosis that ultimately impedes fluid accumulation. If aspiration is used alone, recurrence ranges from 82% to 100%.[99,100] Historically, success rates with aspiration and sclerotherapy vary between 60% and 75% compared to 84–98% with hydrocelectomy.[101–103] However, a recent study using doxycycline sclerotherapy was found to have an 84% success rate with single treatment in hydroceles of less than 750 mL.[100] At this time, doxycycline is the most commonly used sclerosing agent.

For aspiration and sclerotherapy, a spermatic cord block is performed and an angiocatheter (16–19Fr) is inserted through the anterosuperior lateral aspect of the scrotal skin and advanced into the hydrocele. The hydrocele fluid is drained using a syringe, and the sclerosing agent is infused into the cavity of the hydrocele sac.

Hydrocelectomy

Hydrocelectomy remains the main surgical intervention with three techniques described: the bottleneck, Lord, and window procedures. The bottleneck is effective for large hydroceles, while the Lord and window are options for smaller hydroceles. For each procedure, a trans-scrotal incision is made (transverse or longitudinal) over the hydrocele, with dissection down through dartos muscle, external spermatic, cremasteric and internal spermatic fascia in order to deliver the hydrocele sac and testicle into the operative field. The hydrocele sac is then opened longitudinally and the fluid drained. It is important to identify the vas deferens, epididymis, and spermatic vessels in order to avoid injury.

MANAGEMENT OF SPECIFIC COMPLICATIONS

Common complications associated with hydrocelectomy procedures are listed in Table 53.1.

Care must be taken during hydrocelectomy to avoid injury to the structures contained within the fluid sac (Fig. 53.5). These cases are often regarded as being relatively "straightforward," but the normal anatomic relationships between the tunica vaginalis, epididymis, vas deferens, and vascular structures are often markedly distorted. Furthermore, many patients will have inflammatory changes and obliteration

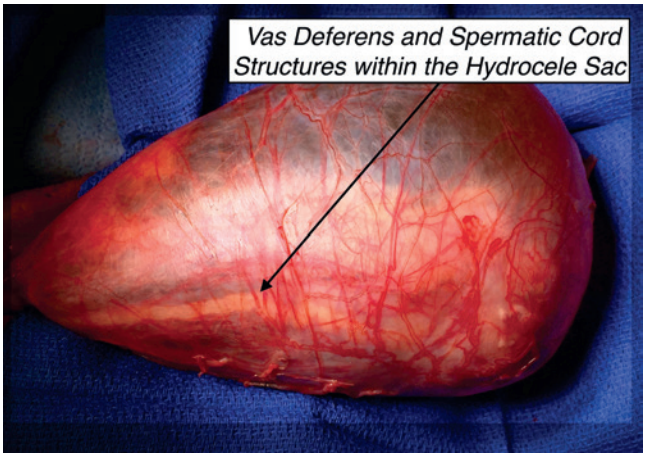


Figure 53.5 Intraoperative photograph depicting the close anatomic proximity of the vas deferens and other spermatic cord structures to the hydrocele sac. Care must be taken to avoid inadvertent injury to these important structures during dissection and resection of the redundant tunica vaginalis that comprises the sac.

of normal tissue planes with adherence of the tunica vaginalis to the key scrotal structures. This is borne out by the fact that *epididymal or vas deferens injuries* may occur in 5.6% of hydrocelectomies.[104] These injuries may occur during excision of redundant tunica or imbrication of the everted tunica, or from an electrocautery injury, and they can result in epididymal or vasal obstruction and obstructive azoospermia.[105] In patients with resultant obstructive azoospermia who are interested in fertility, microsurgical reconstruction is possible, with 5/6 (83%) of patients in one series having return of sperm to the ejaculate; however, it is best to use careful surgical technique and avoid this surgical complication altogether.[106] Just as hydrocelectomy can result in epididymal obstruction, the aspiration with sclerotherapy approach can also cause secondary epididymitis and resultant epididymal obstruction.[101]

Postoperative pain following hydrocelectomy is usually temporary, but development of *chronic pain syndrome* can occur in 0.6–1% of patients undergoing hydrocelectomy.[107,108] Aspiration with a sclerotherapy typically results in pain that resolves in 2–3 days.[100]

Although postoperative hydrocelectomy swelling is common, occurring in up to 9.3% of patients, this is self-limited and usually resolves within weeks to months. *Hydrocele recurrence* following a successful hydrocelectomy has been reported in up to 6% of cases.[107,109] Recurrence rates are far higher for aspiration alone, approaching 100% in some studies.[99,100] Aspiration and instillation of a sclerosing agent has far lower hydrocele recurrence rates (40–60%) than does aspiration alone, but may require multiple treatments.[101,102]

Spermatocelectomy

A spermatocele is a benign, extratesticular, sperm-containing cystic outpouching from the caput of the epididymis.[110] It arises from a dilation of an efferent ductule exiting the rete testes to the caput of the epididymis and is likely related to obstruction of the duct. Spermatoceles are found in up

to 30% of males and are usually small and asymptomatic. Intervention is an option if they become large or painful despite conservative medical management, such as NSAIDs. Spermatoceles are differentiated from epididymal cysts, which are not in direct connection with an efferent ductule and thus do not need to have a connection identified and ligated. In patients who have failed medical management, the gold standard treatment is spermatocelectomy. Treatment such as aspiration of the spermatocele with or without sclerotherapy has been tried but resulted in suboptimal results due to the risk of recurrence, epididymal injury with subsequent obstruction, and sclerotherapy-induced chemical epididymitis.[111]

SPERMATOCELECTOMY PROCEDURE TECHNIQUES

Spermatocelectomies are usually performed under general anesthesia, but they can potentially be performed with regional or local anesthesia. The scrotum is shaved and prepped. Through a midline median raphe or transverse hemiscrotal incision, the tunica vaginalis is opened, and the testicle, epididymis, and spermatocele are delivered. Recent studies have shown the benefit offered by the microsurgical spermatocelectomy approach in reducing postoperative complications, particularly the risk of injury to the epididymis.[112] Dissection continues until the spermatocele neck is identified and subsequently ligated and excised (Fig. 53.6). In order to reduce the risk of injury to the surrounding vessels, the epididymis, and the testicle, bipolar cautery is ideally employed. Once the spermatocele has been excised and hemostasis is confirmed, closure of the tunica vaginalis, dartos, and skin is accomplished using 3-0, 3-0, and 4-0 absorbable sutures, respectively.



Figure 53.6 A spermatocele is shown arising from the caput epididymis. Further dissection was subsequently undertaken to isolate the efferent ductule from which the spermatocele arose. Meticulous operative technique is essential in order of avoid epididymal injury during this procedure.

MANAGEMENT OF SPECIFIC COMPLICATIONS

Common complications associated with spermatocelectomy procedures are listed in Table 53.1.

Complication rates without use of magnification have been as high as 10–30% but drop to 5% with the use of magnification.[108,112–114] The major complications include pain, vasal or epididymal obstruction, spermatocele recurrence, hematoma, hydrocele, infection, and testicular atrophy.

Epididymal injury is of primary concern, particularly in men of reproductive age, as it can result in infertility due to epididymal obstruction.[115] Rates of epididymal injury using the nonmicrosurgical approach have been as high as 17–50% based on pathologic analysis of the resected spermatocele that demonstrated the presence of epididymal tissue.[104,115] This decreased to 0% in a series of 36 microsurgical spermatocelectomies. This study also demonstrated no evidence of reduced semen parameters on postoperative semen analysis.[112]

Recurrence rates as high as 5–10% have been reported in those undergoing nonmicrosurgical approaches, but were 0% at 17 months in those having undergone the microsurgical approach.[112]

Pain associated with spermatocele is improved in 94–100% of patients that undergo surgery for a symptomatic spermatocele.[112,116]

Radical, Partial, and Simple Orchiectomy

Radical orchiectomy is performed for testicular and paratesticular malignancies, while a partial orchiectomy is sometimes an option for a polar testicular lesion (<2 cm) in a solitary testicle or in patients with bilateral testicular masses. Simple orchiectomy is performed for surgical castration (bilateral orchiectomy), nonviable testicle due to torsion or atrophy, recurrent testicular infection/abscess, and refractory testicular pain/scrotal pain.

RADICAL AND PARTIAL ORCHIECTOMY PROCEDURE

An inguinal orchiectomy is performed through a 3- to 5-cm inguinal incision. Care must be taken to identify and avoid injury to the ilioinguinal nerve, which is often adherent to the underside of the external oblique fascia. Once the nerve has been identified, it can be isolated and retracted laterally. The spermatic cord is then isolated from the canal, encircled with a 1/4-inch Penrose drain, and secured proximally with a hemostat. Proximal dissection of the cord to the internal inguinal ring is done to mobilize the cord further, and the testicle is delivered via scrotal pressure from below and gentle traction on the cord from above. Once the testicle is delivered into the inguinal incision, the gubernacular attachments are released and a clamp is then placed proximally securing the cord at the internal ring. The cord is

separated into two bundles for separate ligation and transection, and a 0-silk tie is placed proximally on each bundle and is followed by a more proximal 2-0 silk suture ligature. The clamp at the internal ring is removed to ensure hemostasis of the cord. Closure then occurs with care to avoid injury to the ilioinguinal nerve.

If a partial orchiectomy is being performed, rubber shods instead of a heavy clamp can be placed on the cord to reduce the risk of injury to the vasculature. Some have advocated not clamping at all to reduce the risk of ischemia.[117] A partial orchiectomy can be performed under cold ischemia using ice slush to minimize the risk of ischemic injury to the testicle. An ultrasound is used to define the margins of the tumor, and then the tumor is excised using bipolar electrocautery and blunt dissection. A rim of 5-mm normal parenchyma typically provides an adequate surgical margin. The mass is sent for frozen section, and if it returns benign, closure can commence. If it is malignant, biopsies of the resection bed are needed to confirm complete tumor excision. Biopsies of the surrounding parenchyma are performed to assess for testicular intraepithelial neoplasia (TIN), which is present in the surrounding parenchyma in up to 82% of patients who are found to have a malignancy on frozen section.[117] Closure of the testicle following hemostasis and removal of the rubber shods is accomplished using 5-0 absorbable suture.

A simple orchiectomy is performed through a transscrotal approach with either a midline raphe incision or transverse hemiscrotal incision. The spermatic cord is identified and divided in a manner similar to inguinal orchiectomy. Testicular prosthesis can be placed at the time of radical or simple orchiectomy in patients who have concerns about the cosmetic scrotal appearance.

MANAGEMENT OF SPECIFIC COMPLICATIONS

Common complications associated with orchiectomy procedures are listed in Table 53.1.

The overall risk of *infection* following radical orchiectomy is 1%, with few patients requiring surgical intervention.[118] The risk is higher in the special setting of simple orchiectomy for a nonviable testicle secondary to recurrent orchitis/testicular abscess. In these cases a Penrose drain should be left for 24–48 hours to reduce the risk of postoperative infections. Concurrent insertion of prosthesis at the time of radical orchiectomy is not associated with an increased risk of abscess formation (0–1.3%).[119,120]

Significant postoperative *pain* is experienced in 60% of patients in the hours following surgery, which decreases to 8% several weeks after surgery and to 1.8% at a year postoperatively.[118] *Injury to the ilioinguinal nerve* is rare and can cause immediate postoperative pain and/or hyperesthesia or hypoesthesia. In the event of *ilioinguinal nerve entrapment, patients typically present with pain that presents in a more delayed fashion*. Although incision site pain is usually transient, *phantom testis syndrome* is a phenomenon that has been shown to occur in 25% of patients postorchiectomy, with higher rates among patients who experienced preoperative testicular pain. On average, phantom testis syndrome symptoms begin >2 months following surgery, with 40% of patients having a specific trigger such as urination, exercise, or sexual activity/ejaculation. Although 43% of patients experienced the pain monthly, 28% of patients who report phantom testis syndrome experience permanent pain. Treatments used by patients include analgesics, homeotherapy, thermotherapy, and acupuncture.

Reduced semen parameters are seen in up to 50% of patients with testicular germ cell tumors prior to radical orchiectomy.[121,122] Preorchiectomy azoospermia has been reported in up to 11% of patients.[123] Most patients who do not undergo adjuvant therapy experience an improvement in semen parameters by 2 years following radical orchiectomy, but some will have worsening of semen parameters. Twenty percent of patients will remain persistently oligospermic and 5% azoospermic.[121,123,124] This emphasizes the importance of considering pre-orchiectomy sperm cryopreservation.

Following a partial orchiectomy, 50% of eugonadal males have preservation of fertility.[125] A *hernia* may develop in <1% of patients.[118] *Testicular atrophy* occurs in 3–5% of cases after partial orchiectomy.[126]

Conclusions

Surgical procedures involving the testicle, vas deferens, epididymis, and scrotum are among the most common procedures performed by urologists. Despite the widespread perception that these tend to be straightforward procedures, they are the source of a relatively high percentage of urologic surgical complications. Common themes among these procedures that help mitigate the risk of intraoperative and postoperative complications include proper preoperative evaluation and planning, including cessation of antiplatelet and other blood thinning agents at appropriate time points before surgery. Intraoperative considerations that help diminish the risk of complications include a clear understanding of the relevant anatomy, in particular the vascular anatomy of the spermatic cord. Careful dissection and resection techniques are imperative in order to avoid inadvertent injury to important structures such as the vas deferens, epididymis, and arterial vascular structures. Use of bipolar electrocautery can decrease the risk of thermal cautery injury to the relatively delicate spermatic cord and scrotal structures, and employment of microsurgical techniques can assist in visualization and surgical precision, and thus diminish the risk of operative complications in appropriate cases. Finally, postoperative complications can be minimized through the use of ice packs and compressive scrotal dressings, as well as the avoidance of physical overexertion in the days after surgery.

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Chapter 53 Questions

1. Two days following an elective right hydrocelectomy, a 65-year-old male presents with a temperature of 101.5°F and a large, tender right scrotal hematoma with ipsilateral erythema. Scrotal US imaging confirms the presence of a large right scrotal hematoma, and normal intratesticular blood flow is seen bilaterally. Empiric intravenous antibiotic therapy is initiated. The next best step in management is:
   a. Scrotal support, icing, analgesia, and observation
   b. Scrotal exploration and hematoma evacuation
   c. Interventional radiology arterial embolization
   d. Interventional radiology venous embolization
   e. Percutaneous hematoma aspiration

2. A 38-year-old male undergoes an elective bilateral vasectomy, and 3 weeks postoperatively he provides a fresh semen analysis that reveals one twitching sperm per high power field. The next step is to counsel the patient that:
   a. He should initiate antiinflammatory therapy
   b. His vas deferens was not divided during the procedure
   c. He should ejaculate 10–20 more times and then provide another semen sample
   d. He is cleared to resume unprotected sexual activity
   e. He has experienced vasal recanalization

3. A 38-year-old male presents for consultation regarding correction of a grade III/III symptomatic left varicocele. He asks about the advantages of a microsurgical approach over other approaches. You tell him that the microsurgical approach:
   a. Has a lower risk of recurrence than the nonmagnified inguinal approach
   b. Has a lower risk of infection compared to the nonmagnified inguinal approach
   c. Has an equivalent risk of hydrocele formation compared to the nonmagnified inguinal approach
   d. Has a greater risk of hydrocele formation compared to the laparoscopic approach
   e. Has a greater risk of recurrence compared to the laparoscopic approach

4. A 35-year-old male undergoes a bilateral vasovasostomy procedure, and 2 years postoperatively he still has no sperm on semen analysis testing. He and his wife desire to move forward with efforts for a pregnancy. An intraoperative event that might have resulted in his complication of persistent azoospermia is:
   a. Division of the ilioinguinal nerve
   b. Devascularization of cremasteric muscle
   c. Misalignment of the vasal anastomosis
   d. Preservation of lymphatic vessels
   e. Mobilization of the vas deferens

5. A 46-year-old male initially has a normal sperm concentration and normal motility on postoperative semen analysis testing following a bilateral vasovasostomy procedure. However, four consecutive semen analyses show a progressively declining sperm concentration and motility. He now has rare motile sperm in the ejaculate. The next step in his management is to:
   a. Repeat the semen analysis in 3 months
   b. Schedule a bilateral "redo" vasovasostomy procedure
   c. Schedule a bilateral vasoepididymostomy procedure
   d. Start antiinflammatory therapy or prednisone therapy
   e. Start topical testosterone replacement therapy

6. An advantage of hydrocele aspiration and sclerotherapy over surgical hydrocelectomy is:
   a. A lower recurrence rate
   b. Less postprocedural inflammation
   c. It can be performed under local anesthesia at the bedside
   d. Less postprocedural tissue fibrosis
   e. Better testicular function

7. During an inguinal partial orchiectomy procedure, a patient sustains an ilioinguinal nerve injury. His postoperative symptoms as a result might include:
   a. Decrease of scrotal ruggae
   b. Loss of seminal emission
   c. Epididymal tenderness
   d. Decreased force of cremasteric reflex
   e. Numbness of the scrotum and medial thigh

8. When comparing male surgical contraception (vasectomy) to female surgical contraception (tubal ligation), vasectomy has:
   a. Higher cost
   b. Greater utilization in the United States
   c. Lower risk of injury to visceral organ structures
   d. Shorter postoperative time to sterility
   e. Lower risk of granuloma formation

9. A 42-year-old male undergoes a nonmagnified inguinal varicocelectomy procedure for a grade III/III symptomatic left varicocele. The surgeon does not spare the lymphatic vessels, and the most likely complication to arise from this approach is:
   a. Recurrent varicocele
   b. Testicular ischemia
   c. Epididymal "blowout"
   d. Sperm granuloma
   e. Hydrocele

10. A 50-year-old male undergoes a left partial orchiectomy for a tumor that is found to be benign on final pathology. The patient presents with purplish discoloration and moderate swelling of his left hemiscrotum 3 days later. Scrotal ultrasound reveals intact blood flow to both testicles and a moderate-sized left scrotal hematoma that is not increasing in size. The patient is afebrile, and his pain is well controlled with acetaminophen. The next step is:
    a. Embolization
    b. Completion orchiectomy
    c. Scrotal support, icing, and observation
    d. Percutaneous drain placement
    e. Aspiration

Answers

1. **b.** In the setting of a scrotal hematoma with fever, an infected hematoma is the likely diagnosis. Conservative management with scrotal support, limited activity, and analgesia are insufficient to address the infected hematoma, which requires evacuation. Arterial and venous embolization are generally not indicated in cases of scrotal hematomas and would not address the infected hematoma. Percutaneous aspiration of an infected scrotal hematoma would similarly not provide sufficient drainage and would not facilitate inspection for the bleeding vessel. The correct answer is thus scrotal exploration and hematoma evacuation.
2. **c.** A patient may have viable sperm present in the ejaculate at 3 weeks post vasectomy in the setting of a technically successful vasectomy procedure. This patient is not yet cleared to resume sexual activity given the presence of motile sperm in the semen, and he should thus be instructed to ejaculate 10–20 more times and then provide another semen sample. There is not a role for antiinflammatory therapy in this patient's care at this time.
3. **a.** The microsurgical varicocelectomy procedure is associated with lower rates of recurrence and hydrocele formation than are the nonmagnified inguinal and the laparoscopic techniques. There is no difference in infection rates among these procedures.
4. **c.** Misalignment of the vasal anastomosis can obstruct the vasal lumen and result in vasectomy reversal failure. The other events would not lead to azoospermia on postoperative semen testing.
5. **d.** The decline in sperm concentration following a previous vasovasostomy is suggestive of the complication of delayed failure and may respond to antiinflammatory therapy or prednisone. The patient should be offered sperm banking in the mean time. A "redo" vasovasostomy or a vasoepididymostomy procedure would only be pursued if conservative management efforts fail. There is no role for topical testosterone replacement therapy in a male trying to conceive, as the testosterone inhibits spermatogenesis.
6. **c.** Hydrocele aspiration and sclerotherapy has a significantly higher rate of recurrence than does surgical hydrocelectomy. Given the increased risk of recurrence complications, hydrocele aspiration and sclerotherapy is typically reserved only for seriously ill patients who cannot tolerate a general anesthetic and the risks associated with surgical hydrocelectomy. The aspiration and sclerotherapy procedure is associated with substantial inflammation and fibrosis, and the tissue plane scarring that results from the procedure obliterates the potential space between the tunica vaginalis and the tunical albuginea where the hydrocele fluid collects.
7. **e.** Injury to the ilioinguinal nerve can present as pain, hyperesthesia, or hypoesthesia. The ilioinguinal nerve innervates the scrotum and medial thigh in males, so injury to the ilioinguinal nerve can result in numbness of the scrotum and medial thigh.
8. **c.** Vasectomy is less expensive and has lower utilization rates than does tubal ligation among couples in the United States. While females are sterile immediately after a tubal ligation procedure, it typically takes men months to clear sperm from their ejaculate and be approved to resume unprotected sexual activity. Vasectomy sites occasionally develop sperm granulomas, although these structures do not typically cause substantial bother and rarely require treatment. The correct answer is c (lower risk of injury to visceral organ structures), given that tubal ligation is an intraabdominal procedure and vasectomy is an intrascrotal procedure.
9. **e.** Inguinal and scrotal surgical techniques that do not spare the lymphatic vessels increase the risk of ipsilateral hydrocele formation. Use of microsurgical techniques for varicocelectomy is associated with a decreased risk of hydrocele formation when compared to nonmagnified approaches.
10. **c.** This patient has developed the complication of a scrotal hematoma after his partial orchiectomy. Given that the hematoma is stable and that he is afebrile, observation and supportive measures such as scrotal support, icing, and analgesia are appropriate next steps. Most scrotal hematomas will resolve spontaneously over time with this conservative approach.

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SECTION IX

Complications of Pediatric Urologic Surgery

54 Special Considerations in the Pediatric Patient

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CHAPTER OUTLINE

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KEY POINTS

1. Preoperative family counseling is crucial to a successful outcome.
2. Medical work up is not needed except in high risk patients.
3. Laparoscopic settings, perioperative antibiotics and body temperature differ from adults with child physiology.
4. Airway obstruction, nausea and emesis are the most important immediate post operative concerns.

Introduction

The field of pediatric surgery has greatly advanced since the days when children were treated as small adults. A deeper understanding of pediatric physiology has allowed anesthesia to be administered safely and under the care of specialized providers. Surgeons must also recognize the unique challenges posed by pediatric patients. The majority of patients are healthy and require minimal medical workup. Managing perioperative stress goes beyond counseling the patient and is optimized when a multidisciplinary team is utilized and the entire family is involved. Intraoperative considerations differ from those with adults, ranging from room temperature to insufflation pressures. Postoperative pain control becomes more complex in patients who are unable to verbalize feelings.

In this chapter we aim to review these and many other important issues surrounding pediatric urologic perioperative care. In addition, we will discuss common complications following circumcisions, inguinal surgeries, and pyeloplasties.

Preoperative Considerations

PSYCHOLOGICAL PREPARATION

Perhaps the most demanding task of preoperative surgical preparation for the pediatric population is managing the stress of the patient and parents or other caregivers. While commonly underestimated by the surgeon, operatively induced anxiety can have long-term effects, including nightmares, separation anxiety, eating problems, and increased fear of physicians and health-care institutions.[1] Often the key to reducing stress is to allay the fears of the caregiver, as parental anxiety is known to be transferred to the child.[2] Surgical education begins with the parent or

parents. Confronting parents' fears begins with a comprehensive understanding of the nature, risks, and benefits of the surgical procedure. Reduced anxiety among parents diminishes the patients' anxiety. Depending on the age of the patient, the physician should offer patients the opportunity to speak privately, away from their parents, to address the concerns that the patient may have but is embarrassed to discuss in front of the parents. Additionally, it is imperative to ask appropriately aged children if they have any questions or concerns. Providing age-appropriate reading materials to patients has also been shown to help reduce anxiety.[3]

Preoperative hospital visits provide invaluable educational opportunities for both patients and parents. Arranging for families to meet the anesthesia team preoperatively allows for an introduction to the multidisciplinary approach to modern-day surgery. It also facilitates addressing parental concerns regarding anesthesia as well as patient anxiety surrounding pain control and induction of anesthesia. In addition, many children's hospitals offer behavioral preparation programs run by child life specialists, which have been shown to help reduce perioperative stress levels if conducted 5–7 days prior to surgery.[4] Familiarizing families with the facilities, staff, and surgical process preoperatively helps to alleviate some of the stress associated with the procedure.

Methods to help distract or calm patients on the day of surgery, including video games, music, and sedative premedication, have been shown to be effective in reducing stress levels surrounding surgery.[5,6] However, the most stressful aspect of surgery is the induction of anesthesia. In an effort to ease anxiety, many hospitals allow a parent to accompany the patient into the operating room to be present during induction. While the anxiolytic effect of this intervention on the patient is controversial, parents who accompany their children have been found to have less stress associated with the separation process and have a higher satisfaction level with the overall care provided during the surgical encounter.[7,8]

Many factors outside of our control affect perioperative stress, including previous hospitalizations, patient personalities, and severity of disease.[9] However, there are many programs in place to help ameliorate family anxiety both at the time of preoperative discussion, in the days leading up to the surgery, and also on the day of surgery itself. By optimizing these interventions we not only allow for a smoother day of surgery, but also improve overall satisfaction with the surgical process and decrease postoperative behavioral complications.

PREOPERATIVE WORKUP

Medical Evaluation

The majority of patients undergoing elective pediatric urologic operations are healthy and are having relatively minor procedures. As such, extensive preoperative evaluation is usually not indicated. All patients should undergo a history, including personal or family history of anesthesia complications, bleeding disorders, and a physical examination with special attention to the cardiopulmonary system, to detect any heart murmurs belying structural cardiac anomalies. This evaluation is often done by the pediatrician prior to specialty consultation.

There are a few findings on the day of surgery that can cause complications and potentially lead to surgery being delayed. A skin rash at the site of the surgery is a contraindication to an elective procedure. The presence of an active lower respiratory tract infection is likewise cause for postponement of the procedure. In an otherwise healthy child, an upper respiratory tract infection (URI) is also often an indication for delay. Having had a URI within the last 4 weeks increases the risk for adverse respiratory events with anesthesia.[10] Events include hypoxia, cough, breath holding, laryngospasm, bronchospasms and increased secretions. However, the body of literature suggests that if the anesthesiologist is aware of the URI he or she can accommodate the patient and, in some cases, can safely proceed with the procedure.[11] As such, the decision to cancel surgery is based on many factors relating to the patient's overall health level, age, urgency of the procedure, distance traveled, parental anxiety, and anesthesiologist preference.

Laboratory Evaluation

Most children undergoing elective surgeries do not require routine preoperative laboratory testing.[12] Abnormalities found on CBCs or UAs are typically not clinically significant and do not disclose conditions that lead to the cancellation of the surgery.[13] A hemoglobin of >10 g/L optimizes oxygen delivery so values under this can pose risks during anesthesia.[14] However, the likelihood of finding anemia in an asymptomatic child is small, and thus routine CBCs are not recommended.[15] CBC may be obtained, at the discretion of the surgeon, in populations with higher incidence of anemia, including infants, growing premature infants, and children with chronic disease.[12,16]

More comprehensive testing may be indicated in children undergoing complex surgical procedures. Surgeries with a high risk of hemorrhage or major reconstruction, either within the gastrointestinal or urinary tract, may require a preoperative CBC and chemistries. Additionally, patients with known chronic kidney disease should have preoperative chemistries.

Routine preoperative urinalysis and urine culture are not indicated except in patients undergoing endourologic procedures. Many urologic surgeries involve correcting anatomic abnormalities, and thus these patients are predisposed to urinary tract infections (UTIs). Patients with a history of UTIs should have a urine culture prior to any instrumentation of the urinary tract. For patients who are potty-trained a clean catch specimen is sufficient if it is negative. For younger children, a bladder tap is the gold standard; however, a catheterized specimen is sufficient to provide a representative urine sample.

IMPORTANT MEDICAL CONSIDERATIONS

Premature infants have higher risks when undergoing anesthesia, principally with postoperative apnea. The presence of anemia, specifically with a hematocrit <30%, significantly increases the risk of apneic episodes and elective surgery should be delayed until anemia resolves.[17] The postconceptual age (PCA) is also an important factor in postanesthesia risk. Among patients undergoing herniorrhaphy,

former premature infants who have a PCA of >60 weeks had a <5% incidence of apnea.[18] There is some evidence that using spinal anesthesia instead of general anesthesia decreases rates of postoperative apnea in premature infants and allows for outpatient procedures.[19]

Asthma is another common medical condition in patients undergoing elective procedures. Severity of asthma can often be confused with how well controlled the disease is; mild asthma if not well controlled can appear worse than well-controlled severe asthma. Medical management should be optimized prior to any elective procedure, and, as much as possible, patients should strive to be compliant with all medications preoperatively. All asthma medications should be taken the day of surgery, including inhaled agonists or leukotriene inhibitors. Intraoperatively endotracheal intubation is felt to induce more respiratory complications than a laryngeal mask airway (LMA), and for short procedures standard mask anesthesia is preferred if feasible.[20] Patients may require inhaled agonists intraoperatively to treat bronchospasms or, if on chronic oral or inhaled steroids, may require stress dose steroids to prevent adrenal crisis.

Obesity is an increasing disease among children and has an impact on surgical care. Obese patients are more likely to have comorbidities that affect anesthesia care, including hypertension, type 2 diabetes, and bronchial asthma. Preoperative evaluation should be comprehensive enough to screen for these underlying conditions. Office physical exams may be less accurate at defining true testicular position in obese patients and may lead to use of anesthesia to facilitate exams.[21] Additionally, obese patients are more likely to have anesthesia complications such as difficult intubation, postanesthesia care unit (PACU) upper airway obstruction, and prolonged PACU stays.[22]

Other medical conditions that require special recognition are sickle cell anemia, Down syndrome, and diabetes. Sickling conditions can cause acute chest syndrome, stroke, and myocardial infarction when red blood cells form sludge in vasculature during the perioperative period. Historically it has been recommended to give perioperative transfusions to reduce the Hgb S levels to less than 40%; however, more recent evidence suggests that oral hydration may be sufficient to avoid serious complications after minor, elective surgical procedures.[23] Patients with Down syndrome have a 10–30% risk of having atlantoaxial instability, which can put them at risk for cervical subluxation or dislocation during general anesthesia when the neck is maximally extended for intubation.[24] While routine screening is not generally performed, a plain film of the cervical spine is sufficient to diagnose the condition. Along with the increase in obesity, type 2 diabetes is becoming more prevalent in the pediatric population. Diabetics should have cases scheduled early in the day, and crystalloid fluid containing 5% glucose should be started upon establishment of intravenous access. Half of the patient's morning insulin should be given, and glucose levels should be monitored intraoperatively and in the PACU.

BOWEL PREPARATION

Preoperative bowel preparation serves two roles: For urinary tract reconstruction involving the gastrointestinal tract it reduces gross spillage of enteric contents that theoretically decrease bacterial load if there is a violation of the bowel, and it reduces intraabdominal fecal mass to increase work space in laparoscopic cases. As laparoscopy becomes more prevalent among the pediatric urologic population, bowel preparation becomes an important consideration. A porcine model showed significant increases in intraabdominal volume following bowel preparation,[25] space that can be important in the already cramped confines of a pediatric peritoneum. However, studies examining augmentation cystoplasties in children both via open as well as robotic-assisted laparoscopic approaches have shown no increased operative complications, similar hospital stays, and equivalent results when done without a bowel prep as compared to with a bowel prep.[26,27]

Preferred bowel preparations vary by institution; however, a light mechanical bowel preparation for a laparoscopic case typically involves clear liquids for ≥24 hours preoperatively and a weight-adjusted dose of magnesium citrate (0.5 mL/kg, usually not >200 mL in total dose). More aggressive regimens, including GoLYTELY solution and possible oral antibiotics, can be used in surgeries requiring manipulation of bowel.

Often patients are admitted preoperatively to undergo bowel preparations. This allows for careful monitoring of electrolytes and individual titration of regimen to ensure the bowel is clean. Magnesium citrate can cause hypermagnesemia while Phospho soda-based bowel regimens can lead to hyperphosphatemia and hypocalcemia. Furthermore, patients with chronic kidney disease or neuropathic bowel require special consideration as they are at higher risk for electrolyte compromise.

PREOPERATIVE FASTING

The goal of preoperative fasting is to reduce the volume and acidity of gastric contents to lower the risk of aspiration events during anesthesia and postoperatively. However, there is no literature linking higher gastric volumes to increased aspiration events. In children there is a fine balance between anesthesia risks and risks of dehydration and hypoglycemia. Current guidelines recommend fasting periods of 2 hours for clear liquids, 4 hours for breast milk, and 6 hours for formula, solids, or nonhuman milk[28] (Table 54.1). Studies show that periods of fasting are often longer than recommended, leading to significant preoperative discomfort.[29] In addition, time of fasting does not correlate well with gastric volume.[30] Despite this, aspiration events can

Table 54.1 Guidelines for the Recommended Perioperative Fasting Duration for Healthy Children Undergoing Elective Surgical Procedures

Diet	Hours of Fast
Clear liquids, chewing gum	2
Breast milk	3
Infant formula	4
Nonhuman milk	6
Light meals	6

(With permission from Warner MA, Warner ME, Warner DO, Warner LO, Warner EJ. Perioperative pulmonary aspiration in infants and children. Anesthesiology. 1999;90:66-71.)

have serious consequences and fasting times, if violated, will most likely lead to postponement of elective procedures.

Intraoperative Considerations

ROBOTIC AND LAPAROSCOPIC CONSIDERATIONS

Mirroring trends in adult urologic surgery, laparoscopic and increasingly robotic-assisted laparoscopic procedures are becoming more common. Potential advantages to minimally invasive techniques include better cosmesis, improved visualization of anatomic structures, reduced postoperative pain, and shorter hospital stays.[31] While surgical outcomes have generally been found to be equivalent, these results come out of large-volume centers and are likely not reproducible by surgeons with inadequate training in robotic technique.

There are aspects of pediatric physiology that lead to special considerations when utilizing laparoscopy in children. Children have higher incidences of right to left cardiac shunts, high chest wall compliance, rate-dependent cardiac output, and diaphragmatic respirations, all of which could be negatively affected by CO_2 insufflation.[32] While various hemodynamic and respiratory variables have been seen to change significantly following insufflation for both intra- and extraperitoneal procedures, conscientious anesthesiologists have been able to safely manage patients without complications.[33]

The size of the patient also effects aspects of laparoscopic surgery. The smaller surface area for surgery requires more precise port placement to decrease the likelihood of trocar collisions. Foley decompression during intraperitoneal surgery is essential as the bladder commands a more abdominal position in children. Additionally, a child's abdominal wall is more compliant so lower pressures are used to create adequate working space. Infants (0–2 years), children (2–10 years), and adolescents (>10 years) require pressures of 8–10 mm Hg, 10–12 mm Hg, and 15 mm Hg, respectively.[34] Patients are at higher risk of developing fluid overload due to less insensible losses than with open procedures and reduced glomerular filtration due to increased abdominal pressures.

LATEX PRECAUTIONS

Latex is produced from the sap of *Hevea brasilinesis*, a rubber tree. In the 1980s the rise of transmittable diseases prompted increased use of latex products, and the 1990s saw a rise in latex allergies caused by type I immediate anaphylactic-type reactions as well as type IV delayed-type hypersensitivity reactions in sensitized patients. Pediatric urologists need to be cognizant of latex allergies, as spina bifida patients in particular are the highest-risk population. Historically, up to 60% of spina bifida patients have been found to carry the allergy, with the major risk factor being number of surgical procedures.[35] Latex allergies can be life threatening if children develop intraoperative anaphylaxis, a condition that can be difficult to detect early as warning signs are hidden under surgical drapes.[36] As latex has become a well-recognized allergen, it has increasingly been removed from contact with high-risk patients. Performing latex-free operations on spina bifida patients has shown a decrease in latex sensitization and allergies, with one study finding a decrease in symptoms from 55% to 5%.[37] As latex substitutes become functionally equivalent to latex products, it is prudent to avoid using latex around all high-risk patients.

PERIOPERATIVE ANTIBIOTICS

Currently there are no guidelines for perioperative antibiotic prophylaxis in pediatric urologic procedures. The goal of prophylaxis is to reduce postoperative infections while not exposing the patient to undue harm in the form of allergic reactions, side effects, or resistant organisms. Colonization with "superbugs" is a major concern among our patient population, especially since many have anatomic abnormalities that predispose them to forming UTIs. Perioperative antibiotics are best administered within 60 minutes of the start of a procedure and should end within 24 hours of the procedure.

A recent survey of pediatric urologists revealed that >75% would give antibiotics before open pyeloplasty, hypospadias repair with anticipation of indwelling catheter, reconstructive bladder surgery, endoscopic procedures, and open ureteral reimplantation; most would not give perioperative antibiotics for orchidopexies, circumcisions, simple chordee repairs, or hernia/hydrocele repairs.[38] There is evidence to suggest that the risk of infection is related to the wound class of the procedure. Regardless of procedure site, wound class 2 procedures (clean contaminated) had a 6.7-fold higher rate of infections compared to wound class 1 procedures (clean), suggesting that prophylaxis should be targeted at higher wound class surgeries.[39]

Without any formal recommendations, surgeon judgment should be used when deciding to use antibiotic prophylaxis. In our institution, we use prophylaxis for procedures involving skin incisions in the genital region in pubertal children, in addition to the common procedures listed above. Perioperative antibiotics are also given to children undergoing endoscopic manipulations who take daily prophylaxis.

ANESTHESIA

The fear of anesthesia looms large when parents are considering surgery for their children, often overshadowing concern for the procedure itself. Preoperative hospital visits that allow the parents and patient to meet with the anesthesia team are a powerful tool to reduce anxiety. Often recognition that the anesthesiologists are specially trained to take care of pediatric patients can reassure parents.

Risks associated with pediatric anesthesia have decreased dramatically as the medical field has recognized that child physiology is different from the adult's. Modern anesthesia has proven to be very safe. A single center observational study of pediatric surgeries over a 30-month period showed a perioperative adverse event rate of 79:1000 anesthetics.[40] The majority of intraoperative events were respiratory involving children <1 year of age while 77% of the PACU events comprised vomiting among older patients. There were no anesthesia-related deaths. Despite the overall safety, independent of ASA score, age <1 year predicted adverse events; therefore, all procedures in this population should

involve a specialist provider. A recent systematic review confirmed the safety of pediatric anesthesia, finding that the risk of acute severe complications of anesthesia, defined as "an unexpected perioperative event in a pediatric patient which without intervention by the anesthesiologist within 30 minutes may lead to disability or death," was <1%.[41]

Recently there has been some concern over pediatric anesthetics and neurocognitive development. Rodent models have shown early anesthesia can impair synaptogenesis, causing neuronal apoptosis and subsequent learning and behavioral problems.[42] Overall, observational studies have shown mixed results in the human population. There is evidence suggesting anesthesia, either as a single or multiple exposure(s) during childhood, increases the likelihood of developing a learning[43] or behavioral[44] disability. Bartels et al. conducted a twin study that compared anesthesia exposures prior to age 3 to educational achievement and cognitive problems at age 12. They concluded that anesthesia is a marker for later cognitive impairment, but anesthesia itself is not causal.[45] Currently, more data are needed to determine the effect, if any, of early childhood anesthesia on cognitive development.

HYPOTHERMIA

Intraoperative hypothermia of as little as 1.5–2°C is known to have adverse outcomes, including increased wound infection risk, morbid myocardial outcomes, coagulopathy and need for transfusion, and prolonged recovery and hospital stays.[46] Infants are at high risk for hypothermia due to their thin skin, increased body surface area to weight ratio, and decreased ability to thermoregulate. The most influential factors for decreasing intraoperative body temperature in infants and neonates are OR temperature less than 23°C and major versus minor surgery.[47]

The ideal temperature in the operating room varies by patient age; however, it should approximate the temperature at which the child's oxygen consumption and metabolic rate are minimal. This corresponds to 24–26°C in a newborn or small infant and 21°C in a child.[48] Methods used to maintain the patient's temperature include overhead radiant heat or heated room, warmed blankets and air blankets, prewarmed skin-preparation fluids, warmed IV fluids, and waterproof drapes.

Surgery Specific Complications

COMPLICATIONS OF CIRCUMCISION

Approximately one in three men worldwide are circumcised, with regional prevalence ranging from 75% in the United States to 6% in the UK.[49] Complications occur in approximately 1.5% of these procedures.[50] Complication rates vary depending on how old the patient is when the surgery is completed and whether the procedure is being done as part of a religious ceremony or by a medical practitioner.

Early complications include bleeding, infection, and penile or urethral injury. By far the most common complication is bleeding. Circumcisions performed with a Gomco clamp usually bleed from the frenulum and can be stopped with pressure or with a frenular stitch. If bleeding is coming from a cut skin edge, a hemostatic agent such as silver nitrate can be applied to the area. If there is a large surface area that is oozing with no apparent bleeding vessel, epinephrine-soaked gauze can be used as a compressive dressing to help achieve hemostasis. Often continued bleeding can be due to removal of too much penile shaft skin. The shaft will eventually re-epithelize and no skin grafting is needed but the patient will likely need close follow-up for local wound management for 1–2 weeks. Bleeding that is refractory to the above management, or that results in a large peri-penile hematoma may require surgical exploration.

Infection is a rare early complication. While the penile skin can be difficult to keep clean, the robust blood supply to the organ likely contributes to a low rate of infection.

Although rare, the most serious complications are partial or full-thickness excision of the glans, penile necrosis, urethral injury, or penile amputation. Necrosis typically occurs when "excessive" electrocautery is utilized during the circumcision or if it comes into contact with a metal Mogen or Gomco clamp. It is prudent to use bipolar cautery if needed for hemostasis. Excision of glans tissue is most common with a Mogen clamp when glans tissue is inadvertently pulled into the clamp with the foreskin. Inadequate lysis of adhesions or a high frenular attachment is often the underlying cause of this complication. Proximal migration of the Plastibell plastic ring can occur when it is retained for too long and can cause necrosis of the penis and erosion into the urethra. Additionally, in religious circumcisions the foreskin is often pulled up and pinched between the fingers, which can cause entrapment of the glans tissue. If the glans is amputated it should be wrapped in soaked gauze and placed on ice. Reattachment of the amputated tissue can be successful within 8 hours, and microsurgical technique is usually not needed.[51]

Late complications include meatal stenosis, urethrocutaneous fistulas, skin bridges, and trapped penises. Meatal stenosis can develop in the setting of subclinical inflammation of the meatus unprotected by the foreskin. It has also been hypothesized that ligation of the frenular artery may contribute to stenosis. Stenosis, if symptomatic, requires surgical correction.

Urethrocutaneous fistulas likely develop after crush injuries to the ventral surface of the penis or excessive mobilization of the urethra during freehand circumcisions. Repair is delayed to allow for maturation of the fistula and growth of the penis to facilitate tissue handling.

Penile adhesions following circumcisions are common and do not always require treatment. If symptomatic, adhesions can be managed with a topical steroid cream; however, if they are refractory they may require a circumcision revision. If adhesions become epithelialized they form skin bridges, which will not respond to steroid cream or physical manipulation. Skin bridges require division.

A concealed or trapped penis can develop when the circumcision heals abnormally. A concealed penis occurs in the presence of a prominent suprapubic fat pad that subsumes the penile shaft resulting in deficient shaft skin. A hidden penis typically occurs when too much shaft skin is removed causing inward telescoping of the glans with subsequent scarring of the peri-penile skin over the glans, which may lead to secondary phimosis. This is more likely to occur if there is a preexisting ventral skin deficiency



Figure 54.1 Contraindications to neonatal circumcision. A, Buried penis; B, penoscrotal webbing; C, epispadias; D, micropenis. (With permission from Anthony Caldamone.)

(penoscrotal webbing) that is unrecognized prior to circumcision. Conservative management with betamethasone cream to the scarred skin is effective in 79% of children, the remainder of whom require surgical intervention.[52] If surgery is required, the penis should be degloved and the skin fixed to Buck's fascia to prevent recurrence.

Certain anatomic abnormalities make neonatal circumcisions riskier and should be deferred. The presence of penoscrotal webbing, abnormal urethral meatus, including hypospadias or epispadias, micropenis, or buried penis all warrant a neonatal urology consult (Fig. 54.1). Typically circumcision for these patients is deferred until after 6 months of age and is completed under general anesthesia.

COMPLICATIONS OF INGUINAL SURGERY

Orchidopexy

Orchidopexy is a common urologic procedure with approximately 1% of boys having an undescended testis at 6 months of age. The goal of orchidopexy is to place the testis in a scrotal location to facilitate testicular self-exams at puberty, decrease the risk of testicular cancer, and improve fertility potential. Rates of testicular cancer among boys who have undergone a prepubertal orchidopexy are approximately two to three times greater than unaffected individuals; however, the risk of cancer among uncorrected men is six times greater.[53,54] Semen parameters have traditionally been thought to improve with orchidopexy, especially in patients with bilateral cryptorchidism and when surgery is done at an early age.[55] There are also fertility concerns for unilateral cryptorchidism, as shown by a two-fold increase in the inability to father children among men with unilateral undescended testes.[56] However, the relationship between cryptorchidism, timing of repair, and infertility is still not understood, and recent data suggest orchidopexy, even before 1 year of age, may not improve semen parameters.[57]

Orchidopexy outcomes vary by anatomic position of the undescended testis. Success rates according to testicular position are 74% for abdominal, 82% for peeping, 87% for canalicular, and 92% for beyond the external ring.[58] Reasons for failure are twofold: Either the testicle is located superior to

the scrotum or the testicle has atrophied. Testicular retraction can occur due to inadequate mobilization of the cord, incomplete excision of cremasteric fibers, or inadequate fixation of the testis in the scrotum. Mobilization of the cord requires separation of the processus vaginalis from the spermatic vessels and vas deferens, with a high ligation at the level of the internal inguinal ring necessary if the processus is patent. Mobilization of the cord should be taken to the level of the internal ring. If after these steps there is still tension on the testis, additional length can be gained by preforming the Prentiss maneuver to bring the cord medial to the inferior epigastric vessels, creating a more medial internal ring. Placement of the testis in the scrotum is best accomplished by creating a dartos pouch.

Testicular atrophy results from any injury to the blood supply to the testicle. Inadvertent damage to the spermatic vessels can occur if there is excessive skeletonization of the cord or liberal use of electrocautery. The Fowler-Stephens repair relies on adequate collateralization from the deferential artery and can result in testicular atrophy if the blood supply is not robust. Additionally, inadvertent twisting of the cord when the testicle is pexied into the scrotum can cause ischemia and atrophy.

Neuralgia can develop after inguinal surgery, typically characterized by transient numbness in the distribution of the disturbed nerve or, less frequently, hyperesthesia along the course of the nerve. The ilioinguinal nerve is most commonly encountered during orchidopexy as it runs superficial to the spermatic cord with the cremasteric fibers in the inguinal canal and passes through the external inguinal ring. Care should be taken to identify the nerve and sweep it away from the cord structures to ensure it is not transected or incorporated into the closure of the external oblique. Transection can cause transient numbness of the skin of the inner thigh, upper scrotum, and base of penis. The genital branch of the genitofemoral nerve travels through the inguinal canal where it is vulnerable to injury. Transection of the genital branch causes lateral scrotal skin numbness. The iliohypogastric nerve overlies the internal oblique and perforates the external oblique just lateral to the rectus muscle and superior to the inguinal canal. The sensory distribution of this nerve is similar to the ilioinguinal distribution. The incidence of nerve injuries during inguinal surgeries in children is not reported in the literature. However, among adults undergoing mesh-free inguinal hernia repairs, the incidence of groin pain was 10% and numbness was 25%,[59] suggesting that inguinal surgery can cause a meaningful number of neuropathic complications. Of note, these nerves can also be damaged during laparoscopic orchidopexy with the genitofemoral nerve being the most at risk for injury.

Injury to the vas deferens during inguinal surgery is rare. Blood supply to the vas deferens is delicate, as such excessive skeletonization of the cord, aggressive electrocautery around the vas, and clamping over the vas can all result in unrecognized damage to the vas, which, with time, can lead to obstruction. Inadvertent transection of the vas deferens occurs in 0.2% of pediatric hernia repairs.[60] This most commonly occurs when the processus vaginalis is ligated and will be discovered in the pathology specimen. If a vasal injury is recognized intraoperatively microsurgical repair can be attempted.

Hernia Repair and Inguinal Hydrocele Repair

Hernia and inguinal hydrocele repairs have a similar complication profile to orchidopexies. The genitofemoral, ilioinguinal, and iliohypogastric nerves can all be injured. Dissection of the hernia sac off the cord can cause damage to the vessels, resulting in testicular atrophy, or damage to the vas. Other complications include infection and hematoma formation. The rate of recurrent hernia is 0.4% and need for contralateral repair is 2–8%.[61–63] Scrotal hydrocele repairs have a lower risk of injury to the cord structures but carry a higher risk of infection, hematoma, and recurrence.[64]

COMPLICATIONS OF PYELOPLASTY

Ureteroplevic junction obstruction (UPJO) is a congenital condition caused by a variety of possible etiologies, including intrinsic stenosis, abnormal insertion, aperistaltic segment, and extrinsic crossing vessels or fibrous bands. In the era of prenatal imaging most UPJOs are diagnosed at an early age; however, some children present later with flank pain, flank mass, and UTIs. Indications for repair include symptoms, impaired renal function, or progressive renal loss. In this section we will discuss open and laparoscopic pyeloplasty.

Choice of surgical approach depends on severity of disease, age of the child, and experience of the provider. The most common technique is the Anderson-Hynes dismembered pyeloplasty, with the spiral pyeloplasty typically reserved for long-segment stenosis. Laparoscopic and robotic pyeloplasty are increasingly utilized, with data showing a steeper learning curve versus open procedures; however, experienced surgeons have similar complication rates.[65] Robotic or laparoscopic procedures may have an advantage over open procedures, especially in older children where smaller incisions offer better cosmesis and less pain; however, this is in exchange for higher costs and longer operative times.[66]

The most common complications of pyeloplasty are UTIs and urinary leak. Postoperative UTIs can cause inflammation at the site of the surgery leading to fibrosis and subsequent failure. Preoperative urine cultures should be checked and the urine should be sterile when starting the procedure. Tal et al. found a 12.6% rate of positive urine cultures postoperatively, with a higher rate, although not statistically significant, among stented patients.[67] Infection rates vary widely in the literature depending on definition, with Mufarrij et al. quoting a 2.9% rate of febrile UTI.[68]

Persistent urinary leakage is usually identified by sustained high output from the Penrose drain, which is placed at the site of anastomosis intraoperatively. Other symptoms include pain refractory to typical analgesic regimen, prolonged postoperative fever or ileus, and flank mass. Urinary leaks can be managed conservatively, by retaining the Penrose drain for 5–7 days, but if leakage persists, drainage of the kidney may be required either via a double J ureteral stent or nephrostomy tube. Like UTIs, leaks can cause inflammation and fibrosis at the site of anastomosis and thus may increase failure rates. Ozayar et al. found that early intervention at a median of 4.5 days postoperatively with placement of a nephrostomy tube achieved the same rates of radiographic and symptomatic success as patients

who did not have a complication.[69] The incidence of urinary leaks likely varies depending on the procedure, with one review of the literature finding a 3% rate of leak among stented pyeloplasties versus 8% among unstented pyeloplasty.[70] However, this series found a higher rate of UTIs among stented patients, suggesting there is a trade off when leaving a stent. Stented patients also require a second anesthesia for stent removal. Additionally, proximal migration or breaking of stents can further complicate this procedure. A more recent case series of 367 pyeloplasties found no difference in complication or failure rates between stented and unstented procedures, with the only statistically significant differences being a longer length of stay for stented patients of 0.5 day and a longer period for drains of 6 days in unstented patients.[71]

Pyeloplasty failure is defined by persistent or delayed obstruction. Early obstruction often presents as urinary leak and can be managed conservatively as described above. However, persistent or delayed onset of worsening hydronephrosis or symptoms requires more aggressive treatment. Failure rates are low at 4%[72] and are thought to occur due to fibrosis and restenosis at the anastomosis. Acute complications of UTIs and urinary leak might contribute to fibrosis, along with poor tissue handling, ischemia to the ureter, missed crossing vessels, and tension at the anastomosis. While avoiding an open reoperation for correction is tempting, endopyelotomy[73] and endoscopic balloon dilation[74] have had low success rates when compared to open, laparoscopic, or robotic reoperation. Redo operations may require a spiral technique to traverse a large segment or a ureterocalicostomy if there is a dependent calyx. Salvage rates approach 100% but can require more than one additional procedure. Refractory obstruction in the setting of poor renal function may require nephrectomy.

Postoperative Considerations

POSTANESTHESIA CARE CONSIDERATIONS

Airway Obstruction

Postoperative airway complications involve laryngospasms or stridor. Laryngospasms typically occur directly after extubation but can be seen while patients recover in the PACU. Laryngospasms are more likely to occur in children with blood or secretions in the pharynx or those with a history of upper tract respiratory infections.[75] Initial management includes bag-mask ventilation; however, additional medications or reintubation may be necessary if it persists.

Postoperative stridor is caused by subglottic edema. Risk factors include a history of croup, a history of intubation as a neonate, the use of too large an endotracheal (ET) tube, and the presence of Down syndrome with head manipulation intraoperatively. Traditionally, uncuffed ET tubes were recommended in all children <8 years to prevent stridor; however, recent trends focus on using correctly sized pediatric-specific ET tubes instead of uncuffed tubes.[76] When encountered, stridor should be treated with humidified oxygen and racemic epinephrine. There is also evidence that intraoperative corticosteroids can be used to treat or prevent postextubation stridor.[77]

Nausea and Emesis

Postoperative nausea and vomiting is the leading cause of delayed discharge from the PACU and can lead to unplanned admissions. Risk factors include age >3 years, surgery longer than 30 minutes, and a personal or family history of nausea or vomiting, with the combination of all three leading to a 55% risk of vomiting.[78] Postoperative administration of opioids also greatly increases the risk for nausea and emesis; therefore alternate classes of pain medication should be used if possible. Prophylactic administration of two to three antiemetics is recommended in children at higher risk of emesis. Additionally, oral fluids should be withheld until the child states he or she is thirsty or asks for a drink.

SURGICAL SITE INFECTIONS

Surgical site infections (SSI) cause morbidity for the patient, compromise the cosmesis and occasionally the success of a procedure, and increase the overall costs to the health-care system. The risk of SSIs is related to the wound class and duration of the surgery and appears to be independent of the underlying disease state of the patient.[79] As discussed above, prophylactic antibiotics are indicated in some procedures and can reduce SSIs. However, care should be taken to use prophylaxis correctly. All antibiotics, with the exception of vancomycin, should be administered within 24 hours of incision and should not be continued past 24 hours postoperatively.

There are additional measures that can be taken to decrease SSIs besides antibiotic prophylaxis. A recent quality improvement study showed a 21% reduction in SSIs among high-risk surgeries after initiating a bundle that included preoperative bathing with chlorhexidine gluconate (soap and water for infants <2 months), clippers for hair removal, and chlorhexidine gluconate skin prep (povidone-iodine for infants <2 months) in addition to proper adherence to antibiotic prophylaxis.[80] Chlorhexidine-alcohol skin preparation has been shown to be more effective than povidone-iodine in preventing SSIs and has been approved for use in children above the age of 2 months.[81] Other interventions that have been shown to decrease SSIs include maintaining intraoperative normothermia[82] and avoiding perioperative hyperglycemia in diabetic patients.[83]

FLUID AND ELECTROLYTE MANAGEMENT

Children are more at risk for electrolyte disturbances than are adults due to their smaller size, larger ratio of surface area to volume, and less developed homeostatic mechanisms. Additionally, surgical patients often have net fluid deficits due to preoperative fasting and gastrointestinal losses if a bowel regimen was employed. Intraoperatively, blood loss, third spacing of fluids, vasodilation secondary to anesthesia, and insensible losses, especially in open abdominal cases, compound hypovolemia. Maintenance fluid rates are a standardized method to replete and maintain normovolemia; however, this method must be used with caution as each patient is unique and clinical indicators must be used to determine true volume state. Maintenance rates were initially calculated based on energy metabolism, which itself is a function of surface area and can be calculated based on

weight. In children, maintenance rates can be determined using the Holliday-Segar 4-2-1 rule (Table 54.2). Isotonic solution should be used for hydration in the first 12 hours following surgery, followed by hypotonic fluid.

Postoperative fluid losses should be recorded and appropriately repleted. Patients with diarrhea or nasogastric tube decompression may require different types of fluid replacement as the electrolyte concentration of the fluids lost is unique. Postoperative patients are at risk for hyponatremia; the combination of salt and water retention with high stress-induced ADH levels in the face of ongoing fluid and electrolyte predisposes to hyponatremia. Electrolytes should be checked in patients on prolonged IV hydration. While severe postoperative hyponatremia is a rare event at 0.34%, it has a mortality rate of 8% in otherwise healthy children.[84]

PAIN MANAGEMENT

Adequate pediatric pain management requires a team approach, with opportunities to maximize patient comfort preoperatively, intraoperatively, and postoperatively. While previously misunderstood, it is now widely recognized that infants have well-developed pain perception pathways and require analgesia. One challenge of pediatric pain control is titration, as many infants and children cannot verbalize what they are feeling. Important markers of pain in infants include tachycardia, hypertension, sweating, posturing, facial expressions and crying. Children should be given a visual analog scale, such as the Wong-Baker FACES Pain Rating Scale (Fig. 54.2), to obtain objective ratings.

Regional anesthesia can be very effective at controlling initial postoperative pain. Common blocks in urology include caudal blocks, ilioinguinal/iliohypogastric nerve blocks, and penile blocks. Anatomic landmarks are used to identify the site of injection; however, if they are difficult to palpate ultrasound is increasingly being utilized. Blocks typically contain ropivacaine or bupivacaine with a maximum dose of 2.5 or 3 mg/kg respectively and provide relief for 2–8 hours. When administered prior to the incision, regional anesthesia decreases the amount of general anesthetic needed and, depending on the duration of the procedure, postoperatively decreases pain scores, opioid use,[85] and nausea.[86]

After major surgery patient controlled analgesia (PCA) can be an effective option in children ≥5 years. PCAs allow frequent patient-initiated administration of low-dose narcotics with parameters for lock-outs and total dosage maximums. Among patients who cannot self-initiate medications due to age, developmental, or physical limitations, nurses or caregivers can safely serve as a proxy and provide the stimulus for medication delivery.[87] Basal rates of analgesia can be administered and aid in promoting sleep at night; however, this can cause undue sedation, and therefore frequent monitoring is needed. Morphine is administered at 25 μg/kg/dose and hydromorphone is administered at 4 μg/kg/dose, both with a lockout at 8–10 minutes. For patients with lower analgesia requirements, IV narcotics, including morphine, hydromorphone, and fentanyl, can be administered every 2–4 hours,as needed.

Nonnarcotic IV analgesics are an important adjunct as they do not carry the same side effects of sedation, respiratory depression, and constipation. Ketorolac is an IV NSAID that has been shown to have similar efficacy to morphine.[88] Ketorolac is safe in infants >1 month old; however, it should not be used in patients with renal impairment or an abnormal coagulation profile. It is dosed at 0.5 mg/kg every 6–8 hours and use should not exceed 48–72 hours. IV acetaminophen is another nonnarcotic that is safe in infants

Table 54.2 Maintenance Intravenous Fluids for Pediatric Patients Undergoing Surgical Procedures

Patient Age Group	Initial 12 Hours	Maintenance Thereafter
Infants (<6 mo)	D5 ¼ NS at 1.5 (MR)	D5 ¼ NS at MR
Children (>6 mo)	D5 LR at 1.5 (MR)	D5 ½ NS + 10 mEq KCl/L at MR
Adolescents	D5 LR at 1.5 (MR)	D5 ½ NS + 20 mEq KCl/L at MR
Renal Failure	Avoid potassium	

D5, 5% dextrose; KCl, potassium chloride; LR, lactated Ringer solution; MR, maintenance rate; NS, normal saline

MR: for 0–10 kg give 4 mL/kg/hr
for 10–20 kg give 40 mL/hr + 2 mL/kg/hr
for 20–40 kg give 60 mL/hr + 1 mL/kg/hr

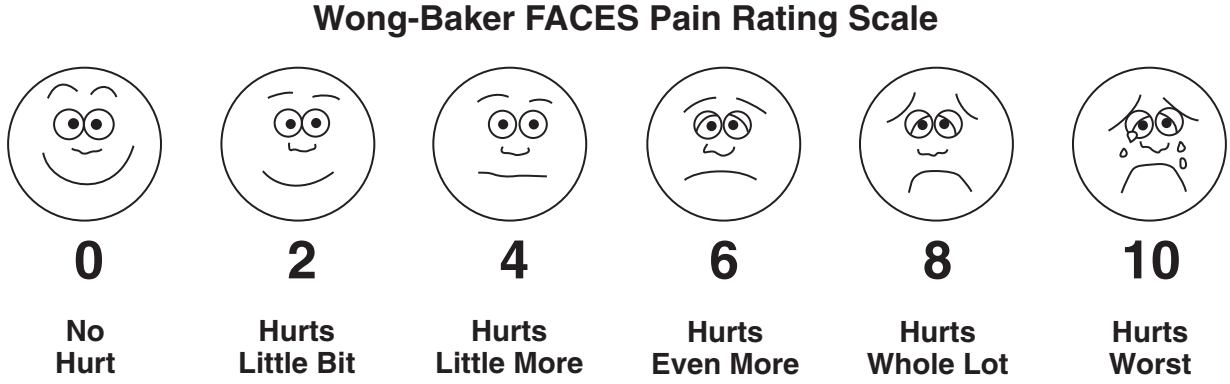


Figure 54.2 Wong-Baker FACES scale. (With permission from Wong-Baker FACES Foundation (2015). Wong-Baker FACES Pain Rating Scale. Retrieved March 17, 2016 from http://www.WongBakerFACES.org.)

and children, dosed at 10 mg/kg/dose every 6 hours with a maximum 24 hour dose of 40 mg/kg. The combination of IV ketorolac and acetaminophen has been shown to halve the use of narcotics and the resultant unwanted narcotic side effects.[89]

For outpatient surgery, there are a number of oral agents that have proven to be effective. Common oral narcotics include combination formulations of codeine or hydrocodone with acetaminophen. Both of these medications come in pill or elixir form and are safe in children >2 years old for hydrocodone and >3 years old for codeine. Dosing is based on the narcotic component with a maximum of 1 mg/kg/dose every 4 hours for codeine and 0.2 mg/kg/dose every 4 hours for hydrocodone. Acetaminophen alone and ibuprofen are two nonnarcotic oral options. Acetaminophen metabolism is delayed in neonates and therefore should be dosed on a 6-hour instead of 4-hour schedule. If prescribing acetaminophen as well as an acetaminophen-containing narcotic, parents should be counseled on maximum dosing of 90–100 mg/kg or 4 g in 24 hours. Ibuprofen is dosed at 10 mg/kg every 6 hours; however, it should be used cautiously if there is a concern for postoperative bleeding. Ketorolac can also be given orally; however, oral use should not exceed 5 days (Table 54.3).

ETHICS

Medical ethics is a nuanced and often enigmatic field that becomes even more complex in the context of pediatric patients. One of the bedrocks of modern medicine, informed consent, weakens when patients are unable to consent for themselves. When approaching an ethical issue, physicians should be aware of the four principles of bioethics: nonmaleficence (avoiding harm), beneficence (providing benefit), autonomy (informed consent), and justice (access to care). In accordance with these moral pillars, prior to any procedure the surgeon should have an open discussion with the parent and child of the risks and benefits of the proposed surgery.

Table 54.3 Dosages for Common Pediatric Pain Medications

Route of Administration	Medication	Dosage
PCA	Morphine	
	Basal	0.03 mg/kg/hr
	Intermittent	0.25 mg/kg/dose
	Hydromorphone	
	Basal	0.004 mg/kg/hr
	Intermittent	0.04 mg/kg/dose
IV	Morphine	0.05 mg/kg/dose
	Hydromorphone	0.01–0.02 mg/kg/dose
	Ketorolac	0.5 mg/kg/dose
Oral	Hydrocodone	0.2 mg/kg/dose
	Codeine	1 mg/kg/dose
	Acetaminophen	10 mg/kg/dose
	Ibuprofen	10 mg/kg/dose

Ethics intersects with pediatric urology practice in a variety of settings. Procedures that are largely cosmetic pose a dilemma, especially when patients are not old enough to participate in the discussion. Circumcision is one such procedure. While the American Academy of Pediatrics' most recent statement in 2012 states the benefits of circumcision outweigh the risks,[90] dissenters argue this guideline has a cultural bias that leads to overstatement of the medical benefits of the procedure.[91] Circumcisions should not be undertaken in the absence of parental consent and consensus.

Disorders of sexual differentiation (DSD) challenge physicians from a medical, surgical, and psychological standpoint. These patients require a multidisciplinary approach with collaboration from urology, endocrinology, genetics, and psychiatry. It is crucial that parents have a firm understanding of their child's condition and realistic expectations for development. Timing of genitoplasty for these patients is very controversial and should not be undertaken until there is some certainty as to which gender the child will identify with. While medical interventions are reversible, surgical procedures are often impossible to undo. Congenital adrenal hyperplasia is the most common DSD and XX patients almost universally identify as females. The majority of specialists would recommend genitoplasty before 2 years of age;[92] however, whether it should be done with a simultaneous reduction clitoroplasty is controversial. Historically, in DSD cases where there was not adequate tissue at birth to perform a phalloplasty, feminizing surgery was undertaken. This practice did not account for the many factors that make up gender identity among this population and is no longer recommended. Huge strides have been made in phallic reconstruction such that phalloplasty is possible before or after puberty.

Neonatal medicine provides another ethical challenge for pediatric urologists. Prenatal ultrasound findings of bilateral hydronephrosis, megacystitis, and oligohydramnios portend poorly for the fetus, and parents turn to the urologist for answers. Ultimately there is no right answer, and it is the urologist's job to give a realistic picture of prognosis using all available clinical data and to present options for both prenatal and postnatal interventions. Long-term healthy survival is now achievable for many of these infants, but requires a team of medical professionals and truly committed parents.

Conclusions

Quality pediatric urologic care requires attention to detail in the preoperative, intraoperative, and postoperative period. Though pediatric patients offer many unique challenges, caring for this population can be a very rewarding experience.

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Chapter 54 Questions

1. Allowing a parent to be present for induction of anesthesia on his or her child has been shown to:
   a. Decrease patient anxiety about anesthesia
   b. Increase operative times
   c. Increase parent satisfaction with surgical experience
   d. Improve quality of anesthesia delivery
   e. Increase risk of surgical site infection

2. A 10-year-old male is having a bladder augmentation. Preoperative urine culture was negative, and there is no history of urinary tract infections (UTIs). What would be the most appropriate perioperative antibiotic regimen?
   a. Ceftriaxone administered 90 minutes prior to incision and continued for 72 hours after the surgery
   b. Vancomycin administered 30 minutes prior to incision and continued for 24 hours after the surgery
   c. No antibiotics are necessary
   d. Gentimycin administered 30 minutes prior to incision and continued for 72 hours after the surgery
   e. Ancef administered 30 minutes prior to incision and continued for 24 hours after the surgery

3. During a religious circumcision in the patient's home the glans is accidentally amputated. How should the family proceed?
   a. Place the glans on ice and transport to the nearest children's hospital
   b. Arrange for transportation to a tertiary center where microsurgical repair could be performed
   c. Wrap the glans in soaked gauze and surround with ice and transport to the nearest children's hospital
   d. Place the glans in the freezer, finish the ceremony, then proceed to the nearest children's hospital
   e. Place a dressing and allow for the wound to heal before a delayed repair

4. When comparing results from stented versus unstented pyeloplasties, stented patients:
   a. Have shorter lengths of hospital stays following pyeloplasty
   b. Have lower rates of urinary leakage from pyeloplasty site
   c. Have lower rates of postoperative UTIs
   d. Have longer periods of Penrose drain postoperatively
   e. Have lower pyeloplasty failure rates

5. A 9-year-old boy with a history of posterior urethral valves with chronic kidney disease and a history of UTIs is undergoing cystoscopy with injection of onabotulinumtoxin A. Which of the following is not indicated?
   a. Basic metabolic panel
   b. Urine culture
   c. Auscultation of the heart and lungs
   d. Questions regarding family history of bleeding disorders
   e. Complete blood count

6. Which of the following is NOT true regarding laparoscopy in children compared with adults?
   a. Lower intraabdominal pressures are needed to create adequate working space
   b. Smaller surface area of skin requires more precise placement of trocars
   c. The bladder is smaller and so does not require decompression with a Foley catheter
   d. CO_2 insufflation can have a larger effect on child physiology due to a higher incidence of right to left cardiac shunts
   e. Both populations accrue similar benefits with improved cosmesis, shorter hospital stays, and reduced postoperative pain

7. All of the following are relative contraindications to neonatal circumcisions except:
   a. Penoscrotal webbing
   b. Micropenis
   c. Abnormal urethral meatus
   d. Buried penis
   e. Dorsal hood with orthotopic meatus and no curvature

8. The nerve at most risk for injury during a laparoscopic orchidopexy is:
   a. Ilioinguinal
   b. Iliohypogastric
   c. Genitofemoral
   d. Pudendal
   e. Obturator

9. An 8-year-old female who 3 years ago had a pyeloplasty for congenital UPJ obstruction presents with left flank pain. Ultrasound shows grade 4 hydronephrosis without ureteral dilation, and a Lasix renogram shows 35% function of the left kidney with delayed wash out. The best surgical option is:
   a. Endopyelotomy of the left UPJ
   b. Endoscopic balloon dilation of the left UPJ
   c. Left ureteral stent placement
   d. Robotic redo left pyeloplasty
   e. Left open nephrectomy

10. Which of the following conditions would not prompt delay of an elective surgery?
    a. Active lower respiratory tract infection
    b. Skin rash at the site of surgery
    c. Consumption of breast milk 5 hours prior to surgery
    d. Poorly controlled asthma
    e. Newly preoperatively detected heart murmur

Answers

1. **c.** While studies have shown mixed results regarding patient metrics, parents have been seen to have an overall improved experience when allowed to accompany their child for the induction of anesthesia.
2. **e.** While there are no specific pediatric urologic guidelines for perioperative antibiotics, an antibiotic should be chosen that covers skin flora, is given within 60

minutes of the operation, with the exception of vancomycin, which should be given at least 60 minutes before the incision. Perioperative antibiotics should not be continued for more than 24 hours.

3. **c.** The amputated tissue should be wrapped in soaked gauze prior to being placed on ice. Direct contact with ice can cause frostbite and compromise the tissue. The repair should be completed within 8 hours of the amputation. Microsurgery is typically not needed so care should not be delayed by trying to reach a hospital where microsurgery is available.
4. **b.** Leaving a ureteral stent appears to lower rates of immediate urinary leakage from the anastomosis site, with rates of leakage being 3% versus 8% without a stent. The literature has shown that stented patients tend to have slightly longer lengths of stay, have higher rates of UTIs, and have the Penrose drain removed earlier. Outcomes of pyeloplasty are the same regardless of stent status.
5. **e.** This patient has a history of chronic kidney disease so a preoperative chemistry is indicated. Likewise, a urine culture prior to instrumentation in a patient with a history of UTIs is warranted. Every patient should have a full history, including family history, and auscultation of heart and lungs prior to surgery. CBC is not indicated in this patient as he has no risk factors for anemia.
6. **c.** The bladder takes up a more abdominal location in children and thus necessitates decompression with a Foley catheter for any laparoscopic procedure. The remainder of the statements are true.
7. **e.** An abnormal urethral meatus is a contraindication as the foreskin may be needed for a surgical repair when the child is older. However, a patient with a dorsal hood in the setting of otherwise normal anatomy can be safely circumcised at birth. Penoscrotal webbing, micropenis, and buried penis all put the patient at risk of having too much skin taken, so it is best to wait until the child is older and a formal circumcision can be performed under anesthesia.
8. **c.** While the ilioinguinal and iliohypogastric nerves are at risk during all orchidopexies, the genitofemoral nerve is the most likely to be injured as it courses with the vas deferens through the inguinal canal.
9. **d.** After initial failed pyeloplasty, redo pyeloplasty either open, laparoscopically, or robotically provides salvage rates approaching 100% in children. Both endopyelotomy and endoscopic balloon dilation have far inferior outcomes. Ureteral stent placement may temporarily relieve the pain; however, it does not treat the underlying condition. Nephrectomy is not indicated in a kidney that has 35% function.
10. **c.** Breast milk can safely be consumed until 4 hours prior to surgery. Active lower respiratory tract infection increases the risks of adverse respiratory events during anesthesia. Skin rash at the site of surgery is an absolute contraindication to an elective procedure. Treatment of medical conditions such as asthma should be optimized prior to an elective anesthesia. A heart murmur can indicate underlying structural heart issues, and the patient should be assessed by a cardiologist prior to surgery.

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55 Complications of Pediatric Endoscopic Surgery

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CHAPTER OUTLINE

Cystoscopic Interventions
Puncture of Ureterocele
Endoscopic Correction of Vesicoureteral Reflux
Incision of Posterior Urethral Valve
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Goals of Therapy
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KEY POINTS

1. Technological advances and miniaturization have increased the ability to treat certain urologic conditions endoscopically.
2. Though complications are generally less common with endoscopic surgery than corresponding open approaches, they can still be significant and warrant equal caution in preventing.
3. Due to the increasing burden of nephrolithiasis among children, the need for optimizing surgical treatment has never been higher.

Cystoscopic Interventions

The miniaturization of optics and instrumentation has allowed endoscopic approaches to certain urologic pathologies. Common cystoscopic procedures include puncture of ureteroceles, endoscopic injection for vesicoureteral reflux, and ablation of posterior urethral valves.

PUNCTURE OF URETEROCELE

A ureterocele is a cystic dilation of the distal aspect of the ureter where it enters the bladder. Embryologically, it is thought to be a remnant of Chwalla's membrane. Ureteroceles are classified into intravesical, extravesical, or ectopic and can be found in both single and duplicated collecting systems. A ureterocele can cause obstruction of the ipsilateral collecting system, leading to loss of kidney function and occasionally obstructive urosepsis if not recognized and addressed in a timely fashion. When intervention is needed, or planned, initial surgery usually entails a cystoscopic ureterocele puncture. Different techniques have been described for ureterocele puncture, but the goal remains the same: Unobstruct and decompress the ureterocele and its accompanying upper tract system, without causing de novo vesicoureteral reflux. The authors prefer incision with a monopolar hot knife or Holmium laser at the base of the ureterocele. Others have described a "watering can" puncture technique with purported lower de novo vesicoureteral reflux, although larger studies are needed for external validation.

Success rates of ureterocele puncture are varied, depending on the number of collecting systems and the type of ureterocele. Some studies report better success – meaning resolution of obstruction and lack of additional procedures – for intravesical ureteroceles compared to extravesical or ectopic ureteroceles. A systematic review and meta-analysis of outcomes following ureterocele puncture revealed a significantly higher risk of reoperation after puncture of an extravesical ureterocele.[1] Rates of reoperation ranged from 0% to 50% for intravesical ureterocele punctures, compared to 48–100% for extravesical ureterocele punctures. This finding remained robust on sensitivity analyses restricting the meta-analysis by duration of follow-up, age at surgery, and duplex systems only. However, heterogeneity and publication bias were both present. Similarly, in the same systematic review and meta-analysis, duplicated systems were at greater risk for reoperation than were single-system ureteroceles after cystoscopic puncture.[1] Rates of reoperation ranged from 0% to 25% for single-system ureterocele punctures, compared to 31–83% for duplicated systems. Heterogeneity was absent, although only three studies were included in this meta-analysis.

One notable complication after puncturing a ureterocele is de novo vesicoureteral reflux into the same

collecting system, although most cases are low grade that self-resolve. Two studies published after the aforementioned meta-analysis demonstrate wide variability in rates of new reflux. At a mean follow-up of 3.8 years, one study of 46 duplicated-system ureteroceles noted decompression of the ureterocele moiety in 56% (26 of 46) of patients with a single puncture and an additional 37% (17 of 46) after two punctures, for a cumulative success rate from cystoscopic intervention alone of 93%.[2] However, these authors did not define de novo reflux as surgical failure. New ipsilateral same-moiety vesicoureteral reflux was noted in five patients (four after one puncture, one after two punctures), with three ultimately requiring endoscopic correction of reflux and two experiencing spontaneous resolution. Another single-institution study reviewed 83 patients (26 single-system, 57 duplicated-system) who underwent ureterocele puncture with a mean follow-up of 24 months.[3] Cure rates, including lack of de novo reflux, were 56% and 15% in single-system versus duplicated-system ureteroceles, respectively. New vesicoureteral reflux into the ureterocele moiety was found in 28% and 56% of single-system and duplicated-system ureteroceles, respectively. Spontaneous resolution of the de novo reflux occurred in four of the five single-system patients, compared with six of the 18 duplicated-system patients.

In summary, cystoscopic puncture of ureterocele offers a minimally invasive approach for initial decompression and the potential for a permanent cure. The rates of success vary by ureterocele location and type of associated collecting system, but repeat puncture can salvage initial failures. New postoperative vesicoureteral reflux may be monitored as with any child with reflux, but spontaneous resolution may be lower in children with duplicated systems.

ENDOSCOPIC CORRECTION OF VESICOURETERAL REFLUX

Vesicoureteral reflux is a common urologic anomaly where urine can reflux from the bladder retrograde to the kidneys. It can be treated cystoscopically with injection of material, such as dextranomer/hyaluronic acid or Deflux, that better coapts the ureterovesical junction to prevent urine from passing retrograde up to the kidney. More details about this procedure and its complications are reviewed in Chapter 56 with the other minimally invasive surgical techniques for treatment of vesicoureteral reflux.

INCISION OF POSTERIOR URETHRAL VALVE

Posterior urethral valves (PUV) are the most common urologic causes of chronic kidney disease renal failure during childhood.[4] They are embryologically related to posterior urethral folds. Because PUV develop early in gestation, the impact on bladder, renal, and pulmonary function can be severe. In a newborn boy with PUV, urethral catheterization is needed to bypass the valves and decompress the urinary system. Once the infant is medically stabilized, he then undergoes a cystoscopic ablation or incision of his PUV. Though there are many methods described of ablating PUV,[5] the follow-up period is critical to monitor for persistent or recurrent obstruction and other complications.

Some experts, including the authors, recommend using a 6Fr or 7.5Fr cystoscope and incising the valves with either a cold knife or monopolar electrode at the 5-, 7-, and 12-o'clock positions to obtain maximum ablation without injuring the external urinary sphincter. The probability of residual valves (i.e., incomplete ablation) ranges from 10% to 33%,[6,7] and 11% of patients have been reported to develop postablation urinary retention.[5] Over a median follow-up of 6.5 years, one of the largest published retrospective cohorts of PUV patients demonstrated other short-term and long-term complications of PUV ablation.[5] Urinary extravasation was noted in three patients, one of whom experienced a rectal injury and subsequent diverting colostomy during antegrade ablation through a suprapubic tract. Gross hematuria occurred in two patients, one of whom required cystoscopic fulguration. At a mean follow-up of 64 months, six of 291 total patients developed urethral stricture disease, with the strictures developing a mean 24 months after valve ablation. All of the patients were treated with direct vision internal urethrotomy, some requiring multiple rounds of urethrotomy, without any need for formal urethroplasty.

Besides persistent and recurrent obstruction, a rarer but just as significant complication following PUV ablation is injury to the urinary sphincter with subsequent urinary incontinence. This can happen when the ablation extends too distally into the external sphincter. One single-institution retrospective review of 67 boys with PUV noted that 34% (23 of 67) had urinary incontinence on median follow-up of 9 years, with only one of the 23 being directly related to surgical etiology of sphincteric incontinence.[8] The remaining boys were thought to have urinary incontinence secondary to bladder dysfunction. Similarly, in another single-institution retrospective cohort of 50 newborn males with PUV, two of the 50 boys had sphincteric incontinence caused by surgical technique at a mean follow-up of 6.8 years.[9] Thus, though injury to the sphincter happens seldomly during PUV ablation, it can occur and must be carefully prevented. The authors stress the importance of small movements of the scope during ablation, with erring on the side of smaller ablative cuts. Immediately following the ablation, a catheter that passes easily into the bladder should be placed for at least 24 hours to dilate the ablated valves. The authors do not place a Foley catheter due to the potential danger of inflating the balloon in the posterior urethra and the theoretical risk of obstruction of the ureteral orifices from an intravesical balloon. We prefer a coudé mentor catheter appropriate to the size of the patient's urethra (e.g., 6Fr in a newborn). Should a patient develop persistent inability to void after initial ablation, then the clinical threshold should be low to trigger a repeat cystoscopic evaluation and repeat ablation if necessary, versus a vesicostomy should a repeat ablation be deemed too risky for sphincteric incontinence. Should suspected sphincteric incontinence occur, the authors recommend confirming with a videourodynamics study once the child is toilet-trained. Depending on the severity and progression of bladder dysfunction when the child is older, construction of a catheterizable channel with bladder augmentation and bladder neck closure may be needed.

Nephrolithiasis

INTRODUCTION

Nephrolithiasis is now a disease that is increasingly being diagnosed during childhood. A recent population-based study demonstrated that the annual incidence of nephrolithiasis has increased 5% per year among 15–19 year olds since the 1990s.[10] The rising prevalence of nephrolithiasis has resulted in an increased need for surgical intervention for younger patients. However, there is substantial variability in the utilization of surgical interventions for children with nephrolithiasis, with the hospital where the surgery takes place one of the most important factors in determining which type of surgery is used.[11] Therefore the need to determine optimal interventions – those that maximize efficacy and minimize risk – is great. This section reviews complications of endoscopic stone surgery for children, namely ureteroscopy (URS) and percutaneous nephrolithotomy (PCNL). Shock wave lithotripsy (SWL) is not covered.

While historically most stones in children were treated with SWL, technologic advancements in miniaturization and optics of endoscopy have allowed an increase in utilization of URS and PCNL.[12,13] According to the American Urological Association 2016 guidelines, URS is considered first-line surgical treatment along with SWL for children with ureteral or renal calculi.[14,15] PCNL is usually reserved for large staghorn stones, large infection stones where clearance is essential, or renal stones in kidneys with abnormal anatomy, such as patients with horseshoe kidneys or urinary diversions.[12] Although the 2016 guidelines state either SWL or PCNL could be performed for children with renal stones >2 cm, we recommend PCNL for large renal stones because of the higher stone-free rates and lesser need for additional procedures, assuming the treating urologist has the appropriate training and experience with percutaneous renal surgery.

A recent systematic review and meta-analysis comparing SWL, URS, and PCNL in adults for lower pole stones <2 cm in size favored PCNL over SWL and URS over SWL, particularly in stones 10–20 mm in size.[16] Another recent systematic review and meta-analysis compared PCNL to URS in adults for any kidney stone and noted higher stone-free rates with PCNL techniques but also higher complication rates, greater blood loss, and longer hospital stay.[17] Whether these results in adults transfer completely to children remains controversial and certainly warrants higher-quality pediatric-specific studies. Additionally, the comparative effectiveness of newer techniques such as mini-PCNL, ultra-mini-PCNL, and micro-PCNL remains to be determined for children with nephrolithaisis.[18]

GOALS OF THERAPY

The goals of surgical intervention for nephrolithiasis are the same for children as they are for adults, i.e., to render the patient stone free with the minimal number of procedures and complications. The choice of intervention is determined primarily by the size and location of the stone and patient anatomy. Secondary considerations include patient comorbidities, composition of stone (if known), experience of the urologist, equipment availability, and wishes of the parents and patient. Additionally, the choice of SWL versus URS is heavily influenced by the site where the child obtains care.[11] One potential explanation for this variation in care is that URS requires greater technical skill and experience than does SWL.

GENERAL CONSIDERATIONS

Radiation

Patients with nephrolithiasis are often exposed to radiation during diagnosis, surgical treatment, and for surveillance after definitive intervention.[19–21] URS and PCNL both typically use fluoroscopy, which delivers ionizing radiation. Cumulative radiation exposure is a particularly important consideration for children with nephrolithiasis given that they are more likely than adults to require future diagnostic imaging and surgical interventions that use ionizing radiation.[22,23] Additionally, the cumulative risk of radiation exposure may be higher in children than in adults because of a longer life expectancy and greater sensitivity of developing tissues to the effects of radiation.

Recent studies have quantified radiation exposure during endoscopic surgery for nephrolithiasis in children. Ristau and colleagues performed a cross-sectional study of all children who underwent ureteral stent placement, URS, and PCNL at the University of Pittsburgh between 2005 and 2012. The median fluoroscopy times for unilateral URS, bilateral URS, and PCNL were 1.6 minutes, 2.5 minutes, and 11.7 minutes, respectively.[24] This was equivalent to 3 mSv for URS and 16.8 mSv for PCNL. Importantly, each patient received a median of one (IQR 1-3) CT scan and three (IQR 1-8) abdominal x-rays for the associated stone episode. The average cumulative radiation exposure for a patient who underwent a CT scan, PCNL, and three x-rays in a 1-year period was 32 mSv. The radiation safety concept – as low as reasonably achievable (ALARA) – emphasizes using the minimal amount of radiation necessary to achieve the desired outcome. Current guidelines recommend a maximum dose of 50 mSv in a 12-month period, and an average of <20 mSv/year over a 5-year period.[25] Thus a therapeutic plan for a single large stone requiring PCNL approaches the limits of recommended ionizing radiation exposure.

Nelson and colleagues also demonstrated substantial radiation exposure for children undergoing ureteroscopy. They note that while fluoroscopy time was the most important determinant of radiation exposure, other factors, such as source-to-skin distance, use of ureteral access sheaths, and dose rate setting, also contributed to total radiation dose.[21] Indeed, three of the four categories that determine the patient's total radiation exposure are modifiable. Of fluoroscopy time, source-to-skin distance, fluoroscopy settings, and patient abdominal wall thickness, only patient abdominal wall thickness cannot be adjusted to decrease delivered radiation. Implementing a 6-item checklist designed to reduce radiation exposure during pediatric URS resulted in a 67% reduction in fluoroscopy time, 78% improvement in skin-to-image intensifier distance, and >90% utilization of appropriate dose settings. Compared to patients who underwent URS prior to implementation of the checklist, radiation exposure was reduced by 87%

among patients who were treated after implementation.[26] Additionally, recent techniques that utilize ultrasound for URS[27] and PCNL[28] help to minimize radiation exposure in children. At the authors' institutions, percutaneous access for PNCL is gained using renal ultrasound. We also use intermittent rather than continuous fluoroscopy when fluoroscopy is needed for URS and PCNL. Fluoroscopy technicians also operate the C-arm and reduce kVp, maximize skin-to-source distance, and narrow the image window to minimize radiation exposure while maintaining image integrity. We avoid routine magnification. Efforts are also ongoing to assess the role of ultrasound-guided URS.

Residual Fragments

Various studies have compared stone-free rates among the surgical treatment modalities. These rates for PCNL range from 70% to 97%, and from 85% to 88% for URS.[29] However, a widespread limitation of the existing literature on endoscopic interventions for pediatric nephrolithiasis means that there is an inconsistency in the definitions of stone-free status after surgery. Often, stone-free rates include ancillary procedures such as SWL. Additionally, different cut-offs for "clinically insignificant" residual fragments are used, which limits effective comparison of outcomes for alternative surgical interventions. Finally, the means by which stone clearance was assessed after surgery are variable. Endoscopy, ultrasound, fluoroscopy, CT scan, and plain film have all been used to define the presence of residual fragments; however, the sensitivity and precision of these methods are highly variable. There is a need to determine a universally accepted and utilized method to define stone clearance after surgical intervention in children.

Ancillary Procedures/Anesthesia

Surgical indications for children with nephrolithiasis are similar to adults. However, the smaller size of children's ureters and kidneys often require additional ancillary procedures to completely and safely remove stones. For example, the smaller size of children's ureters often precludes direct access with a ureteroscope secondary to the risk of ureteral perforation and stricture associated with active dilation. Therefore a ureteral stent is often placed prior to the ureteroscopy to allow for passive dilation of the ureter.[30,31] We routinely "pre-stent" children undergoing URS for kidney stones, particularly if a ureteral access sheath is used; however, we do not typically place a stent prior to URS for ureteral stones. Consequently, the increased stone-free rate with URS compared to SWL needs to be weighed against the greater number of procedures per stone. Future comparative and cost-effectiveness studies should examine the disadvantages and potential harms of surgical interventions along with their efficacy. Such studies will be critical for the development of patients' decision-making tools and their understanding of the impact of alternative interventions on the quality of life for themselves and their families.

URETEROSCOPY

URS has been used to treat children with ureteral and kidney stones since the late 1980s. Initially, the majority of stones extracted were located in the mid-to-distal ureter. Advances in technology, namely miniaturization and improved flexibility, have contributed to the increased use of URS for children and allowed treatment of stones located in the proximal ureter and all areas of the kidney. At our institutions, children undergoing URS are placed in the lithotomy position, similar to adults. However, it is important to use the appropriate-size stirrups to avoid pressure wounds and nerve injuries. We use three sizes of stirrups to provide the appropriate positioning for children of different sizes. For infants, we use gel rolls underneath the knees to provide a modified lithotomy position. Care is taken to ensure all pressure points are padded and the weight of the legs rests on the heels and not the calves or the knees where peroneal nerve injuries may occur.

The success of URS is dependent on stone size. URS should not be considered a first-line treatment for patients with stones larger than 15–20 mm. Additionally, although the efficacy of URS is less dependent on stone position than SWL, consideration must be given to the smaller size of children's kidneys. Smaller kidneys have less room to maneuver a ureteroscope and have sharper angles, which may make accessing stones in the lower pole difficult. Given these technical considerations, we recommend using 150-µm holmium laser fibers to access stones in the lower pole kidney, which have improved deflection compared to larger fibers.[32] We routinely use a 200-µm fiber for ureteral stones and stones located in the mid and upper pole calyces. Studies that compare the efficacy of stone "dusting" and fragmentation with basketing, which are currently ongoing among adult patients, have not been performed among children or adolescents. The authors frequently use a ureteral access sheath if basketing is required.

The complications of URS include ureteral injury, urinary tract infection, and bleeding. Serious complications (greater than Clavien III) are, in most reports, uncommon. In a recent systematic review, the overall stone-free rate for URS was 85.5% and complications occurred in 12% of patients. Only 2% were greater than Clavien grade III.[33] However, the definition of "success" is ill defined and varies substantially among studies. The method of assessing stone-free status ranges from visual inspection at the time of ureteroscopy to postoperative ultrasound or CT. It is thus difficult to directly compare the results and complications associated with different techniques, stone sizes, and stone locations. Generally, stone-free rates are lower for renal compared to ureteral stones (Fig. 55.1).

Although the comparative effectiveness of pre-stenting versus active ureteral dilation to allow primary passage of the ureteroscope has not been systematically examined, adverse outcomes such as ureteral perforation and stricture may be more common if placement of a ureteral stent is not placed prior to the URS to allow for passive ureteral dilation.[12,34] Complications that occurred among patients in whom a ureteral stent was not placed prior to URS include ureteral injury, ureteral stricture, and conversion to open surgery. In one recent report, 19% of children undergoing URS who did not have a ureteral stent placed prior to URS required open ureterotomy with or without ureteroneocystostomy due to a small ureteral orifice.[35] As mentioned above, if the scope or access sheath cannot be advanced easily up the ureter, a 4.6 or 4.7Fr ureteral stent is placed to passively dilate the ureter for at least 2 weeks before



Figure 55.1 Ureteropelvic junction obstruction that resulted from impacted proximal ureteral stone. The patient underwent a successful robotic pyeloplasty.

returning for the formal URS. We recommend against active dilation of the distal ureter because of the risk of ureteral injury and because the diameter of the ureter proximal to the ureteral orifice also limits safe ureteroscopy, particularly if an access sheath is used.

If a ureteral stricture is encountered or develops after ureteroscopy, a retrograde pyelogram can show the degree, length, and location of narrowing. Short midureteral strictures can undergo prolonged stent placement. Balloon dilation is used sparingly by the authors, with laser incision being preferred. We recommend formal reconstruction, which can often be performed robotically, for longer, denser, or recurrent strictures. Distal strictures may be treated with a ureteroneocystostomy. Proximal or midureteral strictures may necessitate pyeloplasty or excision and primary anastomosis, respectively.

A selection of contemporary studies on URS among children is shown in Table 55.1 along with a selected few studies from early in the URS experience to allow comparison of patients and stone characteristics, ureteroscopes, outcomes, and complications.

PERCUTANEOUS NEPHROLITHOTOMY

Percutaneous nephrolithotomy is the preferred intervention for larger renal calculi. The size cut-off has not been well established for children. A poor-quality randomized trial demonstrated that stone-free rates are higher after PCNL than after URS for children with renal calculi >2 cm;[36] however, the risk of complications is also higher. Complications associated with PCNL include blood loss requiring transfusion, noninfectious fever, sepsis, injury to the kidney (including renal pelvis and ureter), pleural injury leading to hydro or pneumothorax, and prolonged urine leak. Chest complications are higher with a supracostal access, particularly when performed above the 11th rib.[37] At the authors' institution, we use a lower pole access for most stones and use upper pole access staying below the 11th rib for large renal pelvis stones that extend past the UPJ.

The proportion of children who experience some complication after PCNL ranges from 15% to 39%. Although most of these complications are minor, complications greater or equal to Clavien III occur in 1–16% (Table 55.2). The probability of operative blood loss requiring transfusion is consistently <10%. Desai and colleagues demonstrated that the risk of bleeding increases with access tract size.[38] Standard access tracts for adults are 24–30Fr; however, the relative size of 24 to 30Fr tracts in pediatric patients has been estimated to be 72Fr due to the smaller size of children's kidneys.[39] Should significant bleeding occur, we recommend aborting the operation, placing either a Foley catheter or reentry catheter as a nephrostomy tube, and treating as clinically indicated and as one would do for adult patients. Should a renal pelvis injury occur, we recommend stopping the operation and placing an antegrade ureteral stent, if feasible. Treatment of known complications of PCNL in children, including hydrothorax and postoperative bleeding, is similar to adults. Due to the possibility of bleeding requiring embolization or hydrothorax requiring chest tube, we recommend that PCNL only be performed at children's hospitals with a pediatric interventional radiology team capable of performing these procedures.

Miniaturization of access sheaths and nephroscopes and improvements in stone fragmentation technology have allowed the use of smaller access tracts while maintaining stone-free rates at or above 75%. Mini- and micro-PCNL have become increasingly common for large renal stones for both children and adults; however, the terminology is not standardized. Mini-PCNL usually refers to access tracts of <20–24Fr whereas micro-PCNL refers to tracts <10Fr. At the authors' institutions, we obtain renal access in the operating room at the time of the PCNL. We first perform cystoscopy and place an open-ended ureteral catheter to just below the UPJ, which can be used for retrograde pyelograms or instillation of saline to distend the collecting system. We then position the patient prone over gel bolsters and obtain renal access with ultrasound. Rarely, if CT guidance is required for renal access in a child with spinal dysraphism or an aberrantly positioned kidney, a nephrostomy tube is placed by interventional radiology prior to the scheduled PCNL. After placement of two wires (with the safety wire preferentially down the ureter), we use a Cook 18Fr balloon dilator and PTFE sheath for renal access. Children's kidneys, and especially infants' kidneys, are more mobile than adults' kidneys and often push away when obtaining initial needle access and placing the access sheath. Attention to the location of the tip of the balloon in the collecting system and bony landmarks is critical when advancing the sheath under fluoroscopy. If necessary, a retrograde pyelogram can be performed through the ureteral catheter to redefine the collecting system anatomy. Prior to placing a sheath in small children, we trim it to shorten the extracorporal component, which we find improves maneuverability and limits torque on the kidney. After obtaining access, we use a 15/18Fr rigid nephroscope and the ShockPulse lithotripter, which uses both ultrasonic and mechanical energy to fragment and remove the stone(s). The ShockPulse was a paradigm shift for us in the care of children with large renal stones because it combined the greater efficacy of the CyberWand (compared to holmium

Table 55.1 Characteristics, Outcomes, and Complications of Selected Studies for Ureteroscopic Treatment of Nephrolithiasis

Author	Patients	Procedures/ Patient	Age in Years Mean (Range)	Stone Size, in mm Mean (Range)	Stone Location	Type of URS	Size of URS	Primary SFR	Pre-stent (%)	Ureteral Dilation	Post-operative Stent	Ureteral Injury (%)	Fever and/ or UTI
Al Busaidy[41]	43	1.2	6.2 (0.5–12)	12.6 (4–22)	Ureteral	Rigid	8.5–11.5	84	0	balloon	NR	1 (2)	12(24)
Satar[42]	33	1.1	7.4 (0.8–15)	5.3 (3–10)	Ureteral	Rigid	6.9–10	94	0	balloon	12 (34)	NR	NR
Nerli[43]	80	1.1	9.5 (6–12)	10 (7–16)	70% ureteral 30% kidney	Flexible	NR	90	0	Metal dilators	NR	0	5 (6)
Dogan[34]	642	1.1	7.4 (0.3–17)	8.9 (NR)	Ureteral	SR	4–10Fr	90	207 (31)	balloon irrigation pump	???	2 (1)	0 (0)
Yucel[44]	48	1.1	7.6 (0.8–18)	6.6 (4–20)	Ureteral	SR	7.5	84	2 (4)	balloon	31 (61)	1 (2)	NR
Tiryaki[35]	32	1.7	5.9 (0.6–17)	8.8 (4–18)	Ureteral	Rigid and flexible	4.5–7.5	57	8 (20)	none	29 (71)	9 (20)	NR
Erkurt[45]	65	1.1	4.3 (0.5–7)	26 (7–30)	Kidney	Flexible	7.5	83	17 (8)	sheath	NR	2 (3)	10 (15)
Kocaoglu[46]	36	1	5.3 (1–13)	8.4 (4–18)	Ureteral	SR	4.5	97	0	None	16 (42)	0	1 (3)
Chedgy[47]	21	1.5	8.6 (1.4–16)	9.6 (5–20)	Kidney Ureteral	SR Flexible	NR	13 (62)	18 (50)	0	18 (50)	0	1 (3)

Table 55.2 Complications After Percutaneous Nephrolithotomy in Children

Author	Year	N	Mean Age (yrs)	Access Size	Fragmentation	SFR (%)	Fever	Sepsis	Blood Transfusion n (%)	Urine Leak	Pleural Injury	Death	Overall	≥Grade III
Citamak et al.[48]	2015	346	8.5	14–30Fr	Pneumatic Holmium	73	NR	4 (0.3)	41 (12)	NR	4 (0.3)	1 (<0.1)	NR	NR
Daw[49]	2015	26	3.7	14Fr	Holmium	77	4 (15)	0 (0)	1 (4)	2 (8)	0 (0)	0 (0)	8 (31)	3 (11)
Dede[50]	2015	39	5.8	12Fr	Pneumatic Holmium	82	4 (10)	0 (0)	0 (0)	2 (5)	0 (0)	0 (0)	6 (15)	0 (0)
Goyal[51]	2014	158	10	24–30Fr	Pneumatic	85	8 (5)	10 (6)	12 (8)	12 (8)	2 (1)	0 (0)	62 (39)	10 (16)
Zeng[52]	2013	331	7.8	14–20Fr	Pneumatic Holmium	80	23 (7)	13 (4)	10 (3)	NR	2 (1)	0 (0)	51 (16)	5 (1.5)
Ozden[53]	2008	53	9.7	20–30Fr	Ultrasonic Pneumatic	74	NR	NR	9 (17)	3 (6)	1 (2)	0 (0)	NR	NR
Jackman[39]	1998	11	3.4	11Fr	EHL	85	NR	0 (0)	0 (0)	NR	NR	0 (0)	NR	NR

laser) with probes that are small enough (2.1–11.3Fr) to be used in mini-nephroscopes and semi-rigid ureteroscopes. Due to the sharper angles and narrower infundibula of children's kidneys, we often use a flexible pediatric cystoscope and/or flexible ureteroscope to confirm stone clearance and access midpole calyces for residual fragments. Following stone clearance, we routinely place a nephrostomy tube, the size of which depends on the child's age. The authors use a 10 to 12Fr Malecot in infants and a 14Fr Malecot or Foley catheter in adolescents. If there is substantial stone burden and/or substantial edema at the UPJ, we place a ureteral stent in addition to the nephrostomy tube. In this setting, the nephrostomy tube is removed after the urine clears and the patient is safe for discharge, usually on POD 1. At this time there is insufficient evidence that tubeless PCNL is a safe option for children.

The probability of complications in contemporary practice in the United States is uncertain and hard to ascertain. Most of the case series on PCNL, mini-PCNL (access tract <24Fr), and micro-PCNL (~5Fr) have been performed in India, Turkey, and China, often in areas with endemic stone disease and a large volume of children with complex renal calculi. Accordingly, the reports often reflect a high institutional and surgeon experience with PCNL. It is uncertain whether similar results would be found in centers in the United States, where nephrolithiasis among children has become more common only recently.

In conclusion, despite the recent AUA guidelines that state both SWL and PCNL are options for children with renal stones >2 cm, we recommend PCNL for these patients because SWL is simply less effective than PCNL for large renal stones. We also have concerns about the safety of SWL in pediatric patients. It is possible that the recently reported association between SWL to the kidney and hypertension[40] may be greater among children because of the larger area of the kidney affected by the shock waves and the longer life span over which hypertension may develop. However, PCNL and percutaneous renal access in children should be performed only by experienced urologists who have the necessary training and equipment. In order to maximize stone-free rates and minimize complications, we recommend that children with large renal stones be referred to high-volume pediatric kidney stone centers.

Conclusions

In summary, pediatric endoscopic surgery has made tremendous progress with advances in technology. From cystoscopes small enough to ablate a newborn's posterior urethral valves to ureteroscopes thin and flexible enough to retrieve lower pole stones, technology has allowed endoscopic procedures in urology to become safer for our smallest patients.

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Chapter 55 Questions

1. The type of ureterocele with the *least* chance of successful puncture is:
   a. Single-system intravesical ureterocele
   b. Single-system extravesical ureterocele
   c. Duplex-system intravesical ureterocele
   d. Duplex-system extravesical ureterocele
   e. All the above

2. The recommended locations to incise for ablation of posterior urethral valves are:
   a. 3 o'clock only
   b. 6 o'clock only
   c. 12, 5, and 7 o'clock
   d. 3, 6, and 9 o'clock
   e. 3 and 9 o'clock

3. The following is true about ablating posterior urethral valves:
   a. Ablation should be done as soon as the child is born
   b. Do not attempt to ablate or remove all remnants of the valves for fear of sphincteric incontinence
   c. Urethral strictures never occur after ablation of posterior urethral valves
   d. If the patient is too unstable for cystoscopic ablation of the valves, it is acceptable to wait without bladder catheterization
   e. Most urethral strictures from valve ablation will require formal urethroplasty for repair

4. The risk of operative blood loss requiring transfusion for children undergoing percutaneous nephrolithotomy is generally:
   a. <10%
   b. 10–15%
   c. 25–30%
   d. 50%
   e. >50%

5. Risks of percutaneous nephrolithotomy include all of the following EXCEPT:
   a. Radiation exposure
   b. Sepsis
   c. Pleural injury
   d. Steinstrasse
   e. Blood loss

6. Relative to the size of children's kidneys, 24 to 30Fr access tracts have been estimated to be the equivalent to what size tracts for adult kidneys?
   a. 10Fr
   b. 24Fr
   c. 50Fr
   d. 72Fr
   e. 100Fr

7. What is the most important determinant of radiation exposure during ureteroscopy?
   a. Fluoroscopy time
   b. Source-to-skin distance
   c. Fluoroscopy setting
   d. Patient thickness
   e. Ureteral access sheath

8. What is the maximum recommended radiation exposure for a 12-month period?
   a. 50 mSv
   b. 10 rad
   c. 50 gray
   d. 25 mSv
   e. 50 rad

9. What is the upper size limit for stones for which ureteroscopy could be considered a first-line treatment?
   a. 5 mm
   b. 7 mm
   c. 10 mm
   d. 20 mm
   e. 30 mm

10. Which of the following has been associated with balloon dilation of the ureteral orifice?
    a. Vesicoureteral reflux
    b. Sepsis
    c. Ureteral stricture
    d. Easier placement of ureteral access sheath
    e. Successful blind basketing of ureteral stone

Case Study 1

A newborn male is just delivered. Examination of his abdomen shows a very distended lower abdomen. A quick review of his antenatal history reviews bilateral hydroureteronephrosis and distended bladder on ultrasound all throughout pregnancy.

1. What is your clinical suspicion at this point?
   a. Bilateral high-grade vesicoureteral reflux
   b. Posterior urethral valves
   c. Bilateral ureteroceles
   d. Bilateral primary obstructive megaureters
   e. Bilateral ureteropelvic junction obstructions

2. What is the most immediate urologic intervention at this point?
   a. Circumcision
   b. Insertion of urethral catheter
   c. Cystoscopic ablation of posterior urethral valves
   d. Suprapubic tube
   e. Antibiotic prophylaxis

3. Once the patient is stabilized, you take him to the operating room. You insert a cystoscope and find posterior urethral valves. You must be careful about all the following during ablation of the valves EXCEPT for:
   a. Where you incise the valves
   b. How aggressively you incise the valves
   c. Location of the external urinary sphincter
   d. Location of urachus at dome of bladder
   e. Location of valves

Case Study 2

A 14-year-old patient presents with a possible kidney stone to the emergency room.

1. Which of the following imaging modalities to diagnose stone carries the greatest risk of radiation exposure?
   a. Renal and bladder ultrasound
   b. Abdominal plain film x-ray
   c. Noncontrast computerized tomographic scan
   d. Magnetic resonance imaging
   e. Computerized tomographic urography

2. The patient is found on imaging to have a 7-mm stone in his right renal pelvis. Which of the following is NOT recommended as initial treatment modality?
   a. Observation if asymptomatic
   b. Ureteroscopy
   c. Shock wave lithotripsy
   d. Percutaneous nephrolithotomy
   e. Cystoscopy with ureteral stent placement if concerned for infection and obstruction

3. On ureteroscopy, the flexible scope cannot be advanced up the ureter easily. What is the next best step?
   a. Flip the patient into prone position and access antegrade through a percutaneous nephrolithotomy tract
   b. Place a ureteral stent, allow passive dilation, then return in a few weeks
   c. Balloon dilate to 18Fr to allow passage of the flexible scope
   d. Abort the procedure and reschedule ureteroscopy for another day
   e. Abort the procedure and schedule shock-wave lithotripsy for another day

Answers

1. **d.** Duplex-system extravesical ureteroceles have the lowest probability of successful puncture.
2. **c.** Recommended locations for valve ablation are at 12, 5, and 7 o'clock.
3. **b.** Valve ablation should be performed without attempting to removal all remnants of the valves, which an increase the risk of sphincteric incontinence.
4. **a.** Operative blood loss requiring transfusion usually happens in <10% of children undergoing PCNL.
5. **d.** Radiation exposure, sepsis, pleural injury, and blood loss are all risks of PCNL.
6. **d.** 24 to 30Fr access tracts in children's kidneys are equivalent to a 72F tract in adult kidneys.
7. **a.** Fluoroscopy time is the most important determinant of radiation exposure during ureteroscopy.
8. **a.** The maximum recommended radiation exposure for a 12-month period is 50 mSv.
9. **d.** The upper size limit for stones for which ureteroscopy could be considered first-line treatment is 15–20 mm.
10. **c.** Balloon dilation of the ureteral orifice has been associated with injury leading to ureteral stricture formation.

CASE STUDY 1

1. **b.** Posterior urethral valves should be suspected in male infants with bilateral hydroureteronephrosis and distended bladder on antenatal imaging.
2. **b.** Immediate decompression of the urinary system with a bladder catheter should be top priority.
3. **d.** Location of incision, aggressiveness of incision, and location of sphincter should all be considered during valve ablation.

CASE STUDY 2

1. **a.** Renal bladder ultrasound is the first-line imaging modality for pediatric patients presenting with a possible kidney stone.
2. **d.** PCNL is usually reserved for larger stones or staghorn stones.
3. **b.** If the ureteral orifice is too tight for a ureteroscope, passive dilation with a stent placement is the safest and most prudent next step.

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56 Complications of Pediatric Laparoscopic and Robotic Surgery

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CHAPTER OUTLINE

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Laparoscopic Access and Approach
Complications of Access and Port Site Closure
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Pyeloplasty
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Bladder and Lower Ureteral Surgery
Ureteroneocystostomy
Ureteroureterostomy
Appendicovesicostomy and Augmentation Cystoplasty
Testicular and Groin Surgery
Diagnostic Laparoscopy
Laparoscopic Orchiopexy
Laparoscopic Varicocelectomy
Laparoscopic Inguinal Hernia Repair
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Chapter 56 Questions and Answers

KEY POINTS

1. Indications for minimally invasive surgery in pediatric urology are rapidly expanding.
2. Minimally invasive surgical procedures carry unique complications that must be recognized and minimized.
3. Success rates for most minimally invasive operations are comparable to traditional open surgical success rates, but longer-term follow-up is needed.

Advances in surgery have often depended on both technologic *innovation* and *diffusion*. Minimally invasive surgery (MIS) constitutes one such innovation that has revolutionized many fields of surgery. Its diffusion into pediatric urology, though slower than in adult urology, has been accelerating. Indications and opportunities for MIS within pediatric urology have rapidly expanded with the development of robotic-assisted laparoscopic techniques that facilitate complex intracorporeal suturing and reconstruction. Furthermore, improvements in optics and instrument miniaturization have enabled MIS to be used in smaller and younger patients. Additionally, spurred by earlier exposure to MIS procedures during residency training, the next generation of pediatric urologists may be better equipped and more likely to utilize MIS to treat their patients.[1,2]

The growth in MIS procedures, however, must be balanced carefully with their potential limitations and risks. One downside has been the opportunity cost during training of the decreased volume of open procedures that constitute much of reconstructive pediatric urology.[2] Another is the lack of standardized requirements for MIS procedures during residency that may result in variable experience, skill, and ultimately success.[3] The last, but arguably the most significant for the patient, is the unique set of associated surgical complications that can arise during MIS procedures.[4]

Although reported rates of postoperative morbidity following most pediatric urology procedures are low, MIS operations require careful planning and execution similar to open surgery. Not every surgery that could be done through a MIS approach must be done that way. Some surgeries such as redo operations may be more conducive to an open approach. However, if the indication is appropriate, the surgeon's expertise is valid, and the patient is counseled extensively and desires to proceed, then MIS offers the potential for quicker convalescence and less pain compared to traditional open surgery.[5] This chapter is a review of the current indications, techniques, complications, and outcomes of the most common MIS procedures in pediatric urology.

General Principles of Laparoscopy in Children

ADVANTAGES AND DISADVANTAGES

Given appropriate indications for surgery, MIS may confer particular advantages over standard open techniques. Specifically, MIS, which includes both pure laparoscopic and robotic-assisted laparoscopic techniques, has been associated with improved magnification, quicker recovery, shortened length of stay, less pain and analgesic requirements, and more favorable cosmetic outcomes.[5] Two smaller incisions have been mathematically theorized to cause less tension and therefore pain than a single larger incision of the same total size.[6] Conversely, opponents of MIS often prefer the tactile haptic feedback, arguably shorter operative time, and occasional ability to avoid transperitoneal surgery offered by standard "hands-on" open approaches.

Ideally, the well-trained pediatric urologist should feel comfortable with both open and MIS techniques, with tailoring of the approach defined by patient- and disease-specific characteristics. However, for those pediatric urologists who offer MIS surgeries, studies suggest that MIS experience level is the primary predictor of complications.[4,7] Thus, exposure to MIS techniques during the training process and the position of the primary surgeon on the MIS learning curve play critical roles in determining surgical outcomes.

LAPAROSCOPIC ACCESS AND APPROACH

The first key step in MIS once the patient is appropriately positioned and under anesthesia is access to the target anatomic space, which is usually either the peritoneum or the retroperitoneum. Access denotes insertion of trocars, with a plethora of techniques and devices available that have been developed. Access can be broadly dichotomized into open-entry techniques including the Hasson technique[8] and insertion of single-incision laparoscopic surgery (SILS) ports versus closed-entry techniques including Veress needle entry, direct trocar entry, and direct optical trocar entry.[9] At our institution, a modified Veress needle entry is commonly used where a skin incision is brought down to fascia, which is then tented up away from underlying bowel and through which a Veress needle is inserted. The abdomen is then insufflated before a camera trocar is inserted bluntly through the same site where the Veress needle had been inserted.

The traditional MIS access, even to retroperitoneal organs such as the kidney, has been transperitoneal. Retroperitoneoscopic access requires adequate knowledge of and comfort with anatomic landmarks in the retroperitoneum. Given the more limited space in the retroperitoneum, various techniques of trocar insertion, such as, for example, with a balloon trocar, have been described with the primary advantage being avoidance of entering the peritoneal cavity and risking abdominal organ injury or future bowel adhesions.[10,11] Additionally, the development of any postoperative hematoma or urinoma may be contained by the retroperitoneal space providing tamponade. The retroperitoneoscopic approach, in experienced hands, has been shown to be comparable in terms of success and complications to the traditional transperitoneal approaches – as with the laparoscopic pyeloplasty.[12,13]

COMPLICATIONS OF ACCESS AND PORT SITE CLOSURE

In general, MIS compared to open surgery possesses its own unique set of perioperative complications related specifically to gaining and closing access. Misplaced trocars may cause subcutaneous emphysema if insufflation occurs above the fascial plane. At worst, misplaced trocars can cause major vascular or visceral organ injuries that necessitate immediate conversion to open surgery. Conversely, trocar sites that are not closed appropriately raise the possibility of bowel herniation and incarceration (Figs. 56.1 and 56.2).

Overall, complication rates from gaining access are low with no definitive evidence favoring any method over others. A recent Cochrane systematic review of 46 randomized controlled trials compared 13 published techniques of laparoscopic access with regard to mortality, visceral, vascular, and solid organ injuries, gas embolism, and failed entry.[9] In general, complication rates were very low and not all outcomes could be assessed. An open-entry technique such as the Hasson technique was associated with less probability of failed entry compared to a closed-entry technique. Direct trocar entry compared to a Veress needle entry conferred a reduction of failed entry and vascular injury rates. However, the authors cautioned that the overall evidence was of too poor quality to support a single superior technique.[9] By comparison, a survey study of 251 pediatric urologists who performed pure laparoscopic surgery revealed a self-reported overall complication rate of 6%, with the majority being preperitoneal insufflation.[7] The survey respondents demonstrated a significantly higher complication rate with

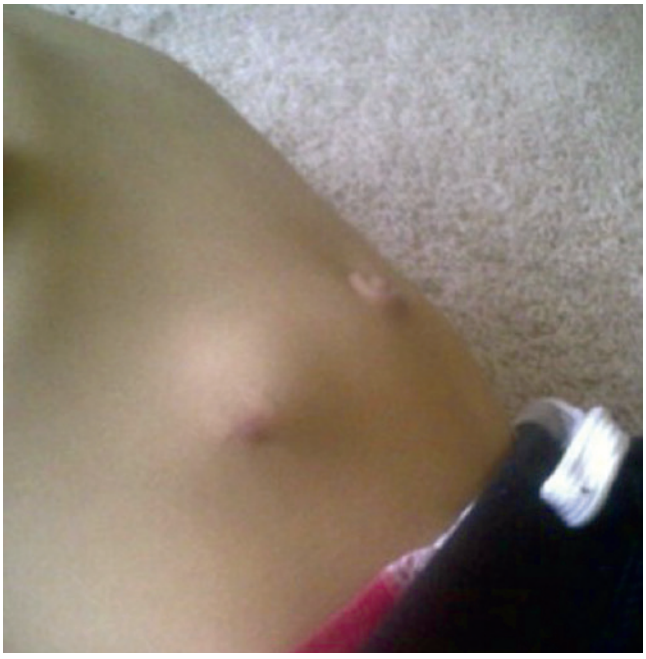


Figure 56.1 Trocar site hernia following robotic-assisted laparoscopic ureteral reimplantation – external view.

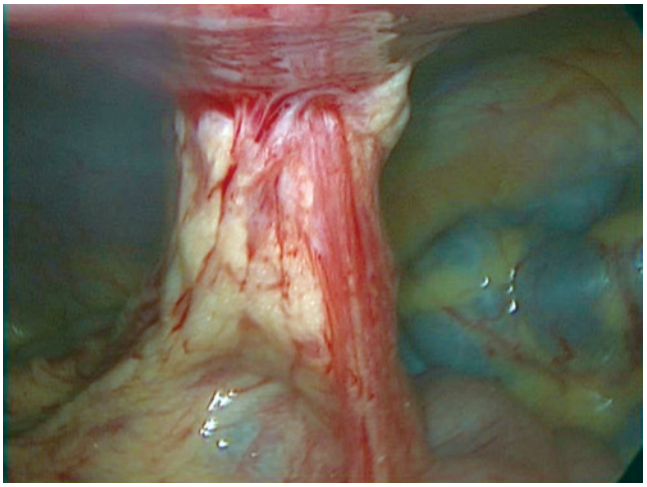


Figure 56.2 Trocar site hernia following robotic-assisted laparoscopic ureteral reimplant – internal view.

Table 56.1 Physiologic Effects of Pneumoperitoneum in Children

System	Effect of Pneumoperitoneum/ Intraabdominal Pressure >10 mm Hg	Potential Complications
Cardiovascular	Increased systemic vascular resistance	Impaired cardiac output Right-to-left flow through cardiac shunts
Pulmonary	Restrictive syndrome	Hypoxemia/hypercarbia, decreased compliance, decreased functional residual capacity
	Increased airway pressures	Barotrauma
Renal	Decreased renal perfusion	Impaired renal function/ oliguria

Veress entry than with open techniques, though the rate of bowel, vascular, or bladder injury requiring surgical repair was still low at 0.39%. Lastly, a retrospective review of more than 800 laparoscopic cases from 1995 to 2005 found an overall complication rate of 2%, including a 1.6% complication rate related to access.[4] The authors noted a higher complication rate with the Veress needle entry (2.3%) than with the open entry (0.8%), but the difference was not statistically significant.

Gas embolism is a notable complication found only in MIS surgery where insufflated carbon dioxide gas inadvertently enters the circulation, leading classically to a mill-wheel cardiac murmur, hypotension, hypoxia, and cyanosis. Treatment entails immediate desufflation of the abdomen and placement of the patient into a left lateral decubitus Trendelenburg position to trap the air before it reaches the pulmonary circulation.

Unique complications may also arise during port site closure. A systematic review of 19 adult studies and three pediatric studies of laparoscopic surgery found a port site hernia rate ranging from 0% to 5.2%.[14] The authors recommended closure of all port sites in younger children (<5 years), referencing one study that found a significantly higher rate of port site hernia in this age group compared to older children.[15] Another study noted that even smaller 5-mm trocars are at risk for bowel herniation, with the authors concluding that all port sites should be closed regardless of size.[16]

ANESTHESIA

The physiologic effects of pneumoperitoneum in children have been well-studied (Table 56.1). In general, pneumoperitoneum to pressures of >8–10 mm Hg adversely affects the heart, lungs, kidneys, and brain during extended exposure. From a cardiopulmonary standpoint, pneumoperitoneum decreases total lung compliance, increases airway pressures, and can affect cardiac output adversely if patients are hypovolemic at the start of surgery or have baseline cardiopulmonary disease.[17] If carbon dioxide is used as the insufflation gas, it can be easily absorbed in children. One prospective study in children found that elimination of carbon dioxide increased after 15 minutes of pneumoperitoneum, continued to climb for another 1 hour, and was significantly higher the younger or smaller the patient.[18] Another observational study of infants <1 year old noted increased peak inspiratory pressures and end-tidal carbon dioxide concentrations and decreased average expiratory tidal volumes and oxygen saturations.[19] Thus, younger patients who undergo MIS may warrant closer observation during and after surgery.

Of note, the cardiopulmonary effects of gas insufflation occur regardless of surgical approach. Both transperitoneal and retroperitoneal laparoscopic surgery were noted retrospectively to increase respiratory rate and peak airway pressures and decrease oxygenation levels.[20] Prospective analyses confirmed increases in end-tidal carbon dioxide levels in both approaches.[21,22]

In addition to its cardiopulmonary impact, pneumoperitoneum may increase systemic vascular resistance. Consequently, renal perfusion may be adversely affected and glomerular filtration rate may decrease. A systematic review of the impact of pneumoperitoneum on renal perfusion and function demonstrated that both were adversely affected in the majority of studies included in the review.[23] Some variability was noted depending on the baseline hydration status of the patient. Regardless, urine output monitoring is critical during MIS procedures, particularly if the case duration is prolonged. Patients with advanced chronic kidney disease may also be at higher risk for worsening renal function and should be counseled accordingly.

SUMMARY

In appropriately selected and counseled patients, MIS is safe, well-tolerated, and is associated with rare, but serious, complications from access and anesthesia. All aspects of gaining and closing MIS access to the peritoneum or retroperitoneum should be performed under careful scrutiny, even if they are not considered the "bulk" of the operation. Though complications are rare, they have the potential to be devastating and could lead to conversion to open surgery or need for reoperation. Without a proven single superior technique for gaining access, we recommend that MIS

surgeons use the access techniques they are most comfortable with and have the most experience doing. Common sense also applies – for example, an open-entry technique such as the Hasson technique may be more appropriate than a Veress technique in a patient with multiple prior intraabdominal surgeries or a thin abdominal wall as in prune belly syndrome. Without safe access before a MIS operation, the rest of the operation may not be possible. Special attention during insufflation with open communication with the anesthesiologist intraoperatively is crucial. Finally, even after a difficult intraoperative procedure is completed via MIS, we recommend increased vigilance during closure of the port sites with special attention to approximation of the rectus fascia even for 5-mm port sites in children.

Kidney Surgery

PYELOPLASTY

The introduction of MIS into pediatric urology has arguably transformed the surgical approach to the dismembered Anderson-Hynes pediatric pyeloplasty. First described as an open approach to correcting a retrocaval ureter in 1949,[24] the technique is utilized to repair the ureteropelvic junction obstruction. Other types of the pyeloplasty such as the Foley Y-V, Culp-DeWeerd spiral flap, and Fenger pyeloplasty have also been developed, but the Anderson-Hynes pyeloplasty remains the mainstay given its successful ability to adapt to crossing renal vessels or intrinsic narrowing at the ureteropelvic junction.

A paradigm shift has been evident in the surgical approach to pyeloplasty. A recent analysis of temporal trends of pyeloplasty from 2003–2010 showed a decline in percentage of open pyeloplasty, a plateauing of pure laparoscopic pyeloplasty, and an increase in robotic-assisted laparoscopic pyeloplasty.[25] Of note, the majority of robotic-assisted laparoscopic pyeloplasties were performed in older children ages 11–18, with most of the open pyeloplasties being performed in infants younger than age 1.

Overall success rates have been over 95% across all open and MIS techniques.[5,12,13,26] Overall complications of pyeloplasty range from 0% to 30% in a systematic review and meta-analysis.[5] These complications include urine leaks, ileus, infections, failures, need for additional interventions, and rare avulsions of the primary renal pedicle or lower pole vessels and bowel injuries. Within this meta-analysis, comparison of MIS versus open approach to pyeloplasty demonstrated similar complication rates. Similarly, robotic-assisted laparoscopic pyeloplasty compared to pure laparoscopic pyeloplasty among children had similar complication rates. Some surgeons, however, posit that the added degrees of movement conferred by the robotic wrist and improved magnification allow for easier intracorporeal suturing than the pure laparoscopic approach. This argument has been supported by evidence of shorter operative times with robotic-assisted laparoscopic versus pure laparoscopic approaches.[5]

Small retrospective studies have examined the role of retroperitoneoscopic pyeloplasty. No significant differences were found between retroperitoneoscopic and transperitoneal laparoscopic techniques in terms of success rates (93% vs 100%, respectively) or complications.[12] The operative time was significantly longer for retroperitoneoscopic pyeloplasty, presumably due to the increased difficulty in suturing the anastomosis in a smaller confined space. Likewise, success rates were comparable between retroperitoneoscopic (97%) and open pyeloplasty (96%) with similar complication rates (29% vs 27%, respectively).[13] Retroperitoneoscopic pyeloplasty did have a 6% conversion rate to open and had a significantly higher rate of anastomotic leakage despite being more commonly stented. Open pyeloplasty, by comparison, had a higher rate of abdominal wall palsy.

In conclusion, pyeloplasty for ureteropelvic junction obstruction remains amenable to MIS approaches with high success rates and complication rates no different from those associated with open techniques. The ability to perform complex intracorporeal reconstruction demonstrated by the robotics platform makes it particularly fitting for pyeloplasty. We therefore expect the temporal trends noted above to continue to increase with a predominance of the robotic-assisted laparoscopic approach in the near future.

TOTAL AND PARTIAL NEPHRECTOMY

Similar to reconstructive kidney surgery in pediatric urology, extirpative kidney surgery also offers opportunities to avail of the benefits of MIS techniques. The vast majority of MIS nephrectomies among children have been for benign pathologies, such as nonfunctional renal units or moieties that continue to cause infections or hypertension. The role of MIS nephrectomies for malignant pediatric pathology, however, continues to be defined.

Initial experiences with MIS nephrectomies predominantly used a laparoscopic approach and were for benign indications.[27–29] One small noncomparative retrospective case series of 26 patients who underwent laparoscopic nephrectomy found no complications, including no urine leak among six patients who underwent heminephrectomy and one who underwent partial resection of a horseshoe kidney.[29] Another study compared 10 children who underwent laparoscopic nephrectomy with 10 children who underwent open nephrectomy, all for benign indications.[27] While operative time was longer in the MIS group, overall hospitalization was shorter. While complication rates were not statistically compared between the two groups, the laparoscopic nephrectomy group had two minor complications, including one colonic serosal injury managed conservatively, compared with five in the open nephrectomy group.

MIS heminephrectomy in duplex kidneys for a nonfunctional moiety possesses certain unique complications compared to total nephrectomy. One such major concern is injury to the blood supply leading to the healthy moiety. Though the exact rates of renal devascularization are unknown, one study of 142 retroperitoneoscopic heminephrectomies in duplex systems found that at a median follow-up of 4.5 years, seven children (5%) ultimately lost function in the preserved moiety requiring completion nephrectomy.[30] The authors note that six of these seven children had previously undergone an upper pole

heminephrectomy, with half of these six experiencing an immediate postoperative complication following the completion nephrectomy. They surmise that unrecognized injury to the renal vessels may occur given the technical difficulty of upper pole heminephrectomy, but they also speculate on the role of pneumoperitoneum and younger patient age as another potential cause of the decline in function in the preserved renal moiety.

Another complication unique to heminephrectomy is the urine leak and formation of urinoma, either due to incomplete excision of the upper moiety renal parenchyma or inadvertent injury to the lower pole moiety collecting system. The rates of urinoma formation range from 0% to 12%, with most usually being asymptomatic and able to be managed conservatively.[31]

Studies have assessed the feasibility and effectiveness of retroperitoneoscopic nephrectomy. One study compared 10 children who underwent retroperitoneoscopic nephrectomy with 13 children who underwent retroperitoneal open nephrectomy.[32] Operative time was no different, but the MIS group had overall shorter hospitalization. Only one complication was noted, a wound site complication in the open nephrectomy group. A systematic review was performed comparing retroperitoneoscopic with transperitoneal laparoscopic approaches for nephrectomy.[28] While the review found many missing surgical indications among the 51 studies included, the vast majority of them were for benign conditions. The overall complication rates were 4.3% for retroperitoneoscopic nephrectomy and 3.5% for transperitoneal laparoscopic nephrectomy. The most common complications were bowel and vascular injuries, hematomas, urinomas, and port site hernias. Subgroup analyses noted vascular injuries in 2/346 and 0/288 kidneys in the retroperitoneoscopic and transperitoneal laparoscopic groups, respectively, with bowel injuries in 2/346 and 1/285 kidneys, respectively.

Though the gold standard for malignant renal tumors such as Wilms' tumors remains open resection through a transverse abdominal incision, small case series have been performed describing MIS nephrectomy. An analysis of 24 children who underwent laparoscopic nephrectomy following neoadjuvant chemotherapy while enrolled in a large European Wilms' tumor trial (International Society of Pediatric Oncology 2001) showed only one complication, a splenic injury, with no cases of tumor rupture.[33] At a median follow-up of 47 months, event-free survival was 96%. However, lymph node sampling, which is a mainstay of surgical Wilms' tumor resection for staging purposes, was inadequately performed in this study in 22 of the 24 children. Another series included 17 children who underwent laparoscopic nephrectomy for various renal malignancies, including Wilms' tumor, renal cell carcinoma, and clear cell sarcoma.[34] Two required conversions to open due to difficulty dissecting free the renal pedicle, but otherwise no other complications were seen. Of note, in this cohort, lymph node sampling was successfully performed in 12 children with a mean yield of 3.4 nodes. One comparative study retrospectively analyzed outcomes of laparoscopic nephrectomy (n = 13) against open nephrectomy (n = 32) for primary renal tumors in children.[35] No cases of tumor rupture occurred, and no difference in operative time was noted, though hospitalization was significantly shorter for the laparoscopic nephrectomy patients. One patient in each group developed an incisional hernia, and one patient in the open nephrectomy group developed a small bowel obstruction. In a subgroup analysis of tumors <10 cm in size to adjust for confounding due to indication, the authors found longer operative time for the laparoscopic nephrectomy patients but still overall shorter hospitalization.

In summary, total nephrectomy for benign conditions remains a suitable indication for the MIS approach, whether transperitoneal or retroperitoneal, with shorter hospital duration compared to open nephrectomy. Conversely, heminephrectomy via MIS techniques is also appropriate, but surgeons must remain wary of the unique risks of complete renal functional loss and urine leak, which may be higher in smaller children. MIS nephrectomy for malignant renal tumors remains exploratory, given the varied ability to sample lymph nodes adequately.

Bladder and Lower Ureteral Surgery

URETERONEOCYSTOSTOMY

The treatment paradigm for vesicoureteral reflux (VUR) continues to rely on the pillars of observation alone, antibiotic prophylaxis, or surgical repair of the congenital defect that facilitates the retrograde flow of urine from the bladder to the renal collecting system while increasing the risk for pyelonephritis. Since antibiotic prophylaxis was recently shown to be superior to observation alone in effectively reducing the risk of pyelonephritis in children with VUR, surgery in the modern era is increasingly reserved for patients with severe grades of VUR who have repeatedly failed prophylaxis.[36]

MIS options for the surgical correction of VUR include the cystoscopic subureteral injection of dextranomer/hyaluronic acid copolymer (Deflux), as well as the pure laparoscopic and robotic-assisted laparoscopic ureteral reimplantation (RALUR). Each procedure conveys varied success rates and, importantly, varying complication profiles.

The endoscopic injection of material into or near the ureteral orifice to coapt the ureteral insertion is arguably the least invasive of the surgical options available for correction of VUR. Though the overall morbidity of endoscopic injection is low, success rates vary greatly. In a meta-analysis of over 5500 patients who underwent endoscopic treatment of VUR, overall success rate as defined radiographically ranged from 78% for low-grade VUR to 51% for high-grade VUR.[37] However, some experts point out that the meta-analysis included other injected material beyond Deflux and believe the volumes of material injected were suboptimal and possibly even half of what should be given.[38] A single-institutional retrospective series of Deflux injections reported much higher success rates of 90% radiographically at 3-month voiding cystourethrogram and 94% clinically.[39] Besides the concern of persistent VUR and pyelonephritis, other complications of endoscopic injection include contralateral de novo VUR and ipsilateral ureteral obstruction. An initial single-institution case series noted 4.5% of patients developed de novo contralateral VUR on follow-up voiding cystourethrogram, leading the authors to inject the contralateral ureteral orifice if it had an abnormal

configuration on cystoscopy.[40] Caution must be taken in overdoing the coaptation. A multi-institutional retrospective analysis of 1155 ureters in 745 patients following Deflux injection from four centers revealed an incidence of ipsilateral ureteral obstruction in seven ureters in five patients that required endoscopic stent placement.[41] Of these five patients, four had secondary VUR from myelomeningocele or severe bladder and bowel dysfunction. Thus, while rare overall, ureteral obstruction may be a higher risk in bladders with abnormal function.

RALUR is most commonly performed using an intraperitoneal, extravesical approach using the technique of Lich-Gregoir, whereas intravesical laparoscopic (or vesicoscopic) ureteral reimplantation is performed less commonly. In the vesicoscopic approach, the bladder is insufflated with carbon dioxide gas and trocars are inserted directly into the lumen of the bladder, and the ureters are mobilized intravesically using the cross-trigonal technique of Cohen.[42]

Various studies have compared the outcomes of RALUR with open ureteral reimplantation, demonstrating mixed results (Table 56.2). One study compared 25 extravesical RALUR patients (mean age 69 months) with 25 open reimplantation patients (mean age 50 months) and noted rates of success in eliminating VUR of 97% and 100%, respectively.[43] While operative time was longer in the robotics group, the length of stay and narcotic pain medication use were less. Three children in the robotics group undergoing bilateral RALUR experienced transient urinary retention. Another retrospective single surgeon series compared 20 extravesical RALUR patients with 20 open extravesical ureteral reimplantations.[44] The authors found comparable success rates, a longer mean operative time in the RALUR group, but significantly less postoperative analgesic requirement. One RALUR patient developed a urine leak and another developed a ureteral stricture that the authors attributed to possible excessive manipulation of the ureter, leading to devascularization of the distal ureter. Another retrospective study compared 20 extravesical RALUR patients to 17 matched extravesical open ureteral reimplantations.[45] Success was >90% across both groups. Extravesical RALUR patients had no difference in operative times, lengths of stay, or analgesia requirements compared to extravesical open reimplantation patients. However, two extravesical RALUR patients experienced urine leaks.

Contrary to the aforementioned studies demonstrating comparable success rates between open and robotic surgical approaches, a retrospective cohort study of 61 patients with a mean age of 6.7 years who underwent RALUR showed a 72% radiologic success rate in eliminating VUR at an average follow-up of 11.7 months.[46] Additional complications of urine leak were noted in 2%, and bilateral ureteral obstruction requiring stents was seen in 5%. Of note, these authors pooled published success rates from 12 RALUR studies, including their own, and found a pooled success rate of 91%, though with evidence of strong heterogeneity across studies.

Other studies have analyzed the outcomes of pure laparoscopic intravesical ureteral reimplantation. The initial description of the technique in 23 refluxing ureters showed a success rate of 96%, but two children experienced transient subcutaneous suprapubic and scrotal emphysema.[42]

Table 56.2 Pediatric Robotic-assisted Laparoscopic Ureteral Reimplantation – Key Studies

Reference	No. MIS Procedures and Approach	No. Open Procedures and Approach	Mean Operative Time (min)	Mean Hospital Stay (hr)	Mean/Median Follow-up (mos)	Success Rate (%)	No. Complications
Smith (2011)[43]	25 extravesical RALUR	25 intravesical open	MIS: 185 Open: 165	MIS: 33 Open: 53	MIS: 16 Open: 29	MIS: 97 Open: 100	MIS: 3 (transient urinary retention, all bilateral cases) Open: 0
Schomburg (2014)[44]	20 extravesical RALUR	20 extravesical open	Unilateral: MIS: 165 Open: 109 Bilateral: MIS: 227 Open: 135	MIS: 25 Open: 34	MIS: 39 Open: 52	MIS: 100 Open: 95	MIS: 2 (1 urine leak, 1 ureteral stenosis) Open: 7 (unknown)
Marchini (2011)[45]	19 intravesical RALUR, 20 extravesical RALUR	22 intravesical open, 17 extravesical open	MIS: 232/233 (intra/extravesical) Open: 147/120 (intra/extravesical)	MIS: 43/41 (intra/extravesical) Open: 69/41 (intra/extravesical)	MIS: 19/12 (intra/extravesical) Open: 12/13 (intra/extravesical)	MIS: 92/100 (intra/extravesical) Open: 93/94 (intra/extravesical)	MIS: 10/6 (4 bladder leak, 1 urinary retention in intravesical; 2 ureteral leak, 2 urinary retention in extravesical) Open: 14/8 (10 bladder spasms/pain, 12 hematuria in intravesical; 7 pain, 2 bladder spasms in extravesical)
Grimsby (2015)[46]	61 extravesical RALUR	No comparator	MIS: n/a	MIS: n/a	MIS: 12	MIS: 72	MIS: 6 (3 ureteral obstruction, 2 urine leak, 1 readmission for nausea/vomiting)

MIS, minimally invasive surgery; RALUR, robotic-assisted laparoscopic ureteral reimplantation

Another case series of 113 reimplanted ureters showed a success rate of 92% with seven patients, all successful cases, developing postoperative urinary tract infection.[47] A third case series of 27 VUR patients who underwent vesicoscopic reimplantation had a success rate of 92%, but two patients developed intraperitoneal urine leaks through port sites in the bladder and one patient who underwent a tapered reimplant developed an anastomotic stricture.[48] One study compared vesicoscopic reimplantation with open reimplantation, with success rates of 91% and 97%, respectively.[49] Operative time was greater and analgesia requirement was less for the vesicoscopic group, with no difference in length of stay. Urine leakage, bladder stone, and bilateral ureteral obstruction were each noted in one child apiece in the vesicoscopic group with none in the open reimplantation group. Lastly, a study comparing 19 intravesical RALUR patients with 22 intravesical open ureteral reimplantation patients demonstrated success rates of greater than 90% in both groups.[45] Intravesical RALUR patients had longer operative time, shorter length of stay, and less narcotic analgesia requirement compared to the intravesical open reimplantation group. However, the RALUR cohort included one child experiencing transient urinary retention, and four patients experienced bladder leak through trocar sites before the closure technique was improved.

The success rates of MIS approaches to resolve VUR are as varied as the surgical options. The possibility that inconsistencies in surgical success rates are secondary to comparisons across heterogeneous cohorts and increasingly selective criteria for surgery must be considered. The results underscore that RALUR is an emerging surgical option that should be utilized by experienced surgeons prepared to address the potential for rare but significant complications including urine leaks, ureteral obstruction, and urinary retention. Multi-institutional studies examining safety and efficacy are underway.

URETEROURETEROSTOMY

In duplex renal collecting systems with ectopic ureters, ureteroceles, or vesicoureteral reflux, the ipsilateral ureteroureterostomy offers a viable surgical option beyond the heminephrectomy of a poorly functional moiety discussed in a previous section. The ureteroureterostomy diverts the offending ureter – typically the upper pole ureter – while obviating the risk of avulsion or injury to the functional lower pole moiety. While the lower pole, or recipient ureter, may be rendered vulnerable during the ipsilateral ureteroureterostomy, published studies seem to suggest that placement of a ureteral stent into the lower pole moiety significantly reduces the risk of stenosis or urine leak.

The initial pediatric MIS experience with ipsilateral ureteroureterostomy was described in eight kidneys in six children in 2007.[50] All cases were performed via transperitoneal laparoscopy with the recipient ureter being prestented. No intraoperative complications were noted. At a mean follow-up of 10.7 months, two patients developed postoperative febrile urinary tract infections but no residual hydronephrosis was seen at 1, 3, and 9-month postoperative ultrasounds.[50] Another retrospective initial case series of the transperitoneal pure laparoscopy approach in seven patients with recipient ureteral stenting reported no intraoperative or postoperative complications.[51] The largest single institutional experience for open and laparoscopic ureteroureterostomy included 41 patients, 12 of whom were treated laparoscopically.[52] After an overall mean follow-up of 2.8 years for the whole cohort, one of the patients developed an anastomotic stricture and one developed a ureterovesical junction stricture thought secondary to stent placement, though the authors did not directly specify whether these patients were from the laparoscopic or open group. No other comparisons were made between the laparoscopic and open groups.

Experience is rapidly increasing with the robotic-assisted laparoscopic ureteroureterostomy (RALUU), and several institutions have reported outcomes while confirming the safety profile of the technique when incorporating prestenting of the recipient ureter.[53–56] A two-institution retrospective series compared 25 RALUU cases with 19 open ureteroureterostomy cases in duplex systems or obstructed single systems.[54] The RALUU patients were more likely to undergo cystoscopy and stent placement, but at mean follow-ups of 16 and 12 months for the RALUU and open groups, respectively, there were no differences in operative times, blood loss, or postoperative complications measured with the Clavien system. Four febrile urinary tract infections were treated in each group, and length of stay favored the RALUU group. Of note, 86% of the RALUU patients had resolved or improved hydronephrosis on follow-up ultrasound, compared with 53% in the open surgery group. While pyelonephritis may be the most commonly reported postoperative morbidity with the RALUU, one published experience posits that the risk of pyelonephritis may be reduced by leaving recipient ureters with indwelling stents (requiring cystoscopic removal) rather than facilitating stent removal with a "dangler" stitch affixed to the distal stent tip.[55] Another study reported an 8-year period of outcomes of robotic-assisted laparoscopic surgery in duplex renal anomalies, including 14 patients who underwent transperitoneal RALUU.[56] All 14 patients had prestenting of their recipient ureter with resolution of hydronephrosis on postoperative imaging for a success rate of 100%. One of the 14 developed a port site hernia. The authors did not report mean follow-up for this subset of RALUU patients.

One of the earlier historical concerns of performing a ureteroureterostomy in duplex systems was the anecdotal "yo-yo" effect, where urine excreted from one moiety would reflux up to the other moiety, potentially contaminating the recipient moiety with infection or urinary stasis. Studies from open ureteroureterostomy cohorts, however, have not substantiated this hypothesized effect. Though admittedly limited, over a mean follow-up of 12 months, all 39 patients undergoing 41 open ureteroureterostomies were noted to have no dilation of the recipient ureter consistent with a "yo-yo" effect or anastomotic stricture.[57]

The results from the MIS ureteroureterostomies, as mentioned previously, note overall good success rates though an outcome of dilation of the recipient ureter may not be specifically listed. As such, longer follow-up in larger cohorts is needed to provide definitive evidence against this particular risk of ureteroureterostomies. One important comparison to make when deciding the surgical approach to a duplex system anomaly is weighing the risk of "yo-yo" pyelonephritis after a ureteroureterostomy against the risk of lower

pole moiety devascularization after an upper pole moiety heminephrectomy, which is 5–8%.[30]

MIS ureteroureterostomy, particularly the RALUU, provides an excellent alternative for the surgical treatment to heminephrectomy for duplex system anomalies. The recipient ureter does require prestenting, but the surgical procedure has high success rates with relatively low complications. While the risk of anastomotic stricture or "yo-yo" reflux remains theoretical at this time, the defined risk of injury to the lower pole moiety in heminephrectomy approaching 10% offers a reasonable argument for continuing to investigate the RALUU as a serious option for the management of duplex system anomalies in children.

APPENDICOVESICOSTOMY AND AUGMENTATION CYSTOPLASTY

As surgeons gain experience with laparoscopic and robotic-assisted surgery, many are beginning to offer even the most complex reconstructive surgical procedures including the appendicovesicostomy (APV) and augmentation enterocystoplasty. The goals of these two procedures overlap: Improve urinary storage and facilitate emptying via a catheterizable channel.

The continence mechanism of the APV is a tunnel through the detrusor layer of the bladder that functions via the flap-valve principle as described first by Mitrofanoff.[58] A small case series of four patients undergoing a pure laparoscopic APV showed a 100% continence rate at a mean follow-up of 12 months, though one was converted to open due to inability to pass the catheter at the end of the case.[59] Mean operative time was 3.5 hours and mean hospitalization was 3.7 days. A slightly larger case series compared 10 patients who underwent robotic-assisted laparoscopic APV against 10 age- and diagnosis-matched patients who underwent open APV.[60] Of the robotic-assisted laparoscopic APV patients, one was converted to open due to an inadequate appendix and one patient developed pulmonary distress postoperatively related to his baseline comorbidities. Median hospitalization was 5 days for the MIS group compared to 8 days for the open group. At a median follow-up of 14 months, three of the 10 MIS patients developed urinary leakage, including one that ultimately required an augmentation cystoplasty. By comparison, at a median follow-up of 18 months, four of the 10 patients in the open group developed postoperative complications, including stomal stenosis in two and pyelonephritis in two. A more recent and larger comparative series included 28 open and 39 robotic-assisted laparoscopic APV patients.[61] At a mean follow-up of 2.7 years, there were no differences between the open and MIS groups in terms of acute complications (29% vs 26%, respectively), overall reoperations (29% vs 33%, respectively), or reoperations within 12 months of surgery (14% vs 26%, respectively). The authors did note, however, that the complications requiring revision surgery differed, with primarily urinary incontinence seen in the MIS group compared to stomal prolapse or stenosis experienced in the open group. Additionally, three patients in the MIS group experienced small bowel obstruction from an internal hernia requiring secondary surgery.

An APV is often constructed in conjunction with simultaneous augmentation enterocystoplasty, particularly for patients with poor compliance or a contracted small bladder. The largest published MIS case series to date compared 15 patients who underwent robotic-assisted laparoscopic augmentation enterocystoplasty with 13 patients who underwent an open augmentation enterocystoplasty.[62] All the augmentations were performed using ileum. Operative time was far greater for the MIS group (623 vs 287 minutes in the open group), though hospitalization was shorter (6 vs 8 days in the open group). At a median follow-up of 43 and 45 months in the MIS and open groups, respectively, complications were not statistically significantly different between the groups. Bladder stones required removal in three patients in each group, but the MIS group also had three patients require stomal revisions.

The cumulative experience with the MIS approach to APV and augmentation cystoplasty remains preliminary at this stage, and larger studies to assess the efficacy and safety of these complex procedures are needed. Preliminary data are certainly promising, though the novice MIS surgeon must be wary of the far longer operative times with the MIS approach – with attendant anesthetic risks – as well as surgical complexity and difficulty.

Testicular and Groin Surgery

DIAGNOSTIC LAPAROSCOPY

Cryptorchidism is one of the most commonly encountered diagnoses in a pediatric urology practice. Of patients with a unilateral undescended testicle, an estimated 20–30% are nonpalpable. Of these, an estimated 50–60% are intraabdominal, 30–40% are inguino-scrotal, and 10–20% are truly vanishing testes.[63] The management of nonpalpable testes has evolved significantly with the development of diagnostic laparoscopy. Pediatric urologists may now easily insert a small laparoscope intraabdominally to determine testicular location and presence or absence of the spermatic vessels and vas deferens on the affected side. Vanishing testes are marked by blind-ending spermatic vessels and vas, whereas the presence of both vessels and vas passing through the internal inguinal ring warrants an inguinal exploration.

Various studies have examined the utility of diagnostic laparoscopy in cryptorchidism. A prospective study of 126 nonpalpable testes in 104 children found that diagnostic laparoscopy was accurate in localizing the testes in 90% of cases, with location confirmed by surgical exploration.[64] Laparoscopy was inadequate in 8% of cases, largely due to preperitoneal insufflation. As such, complications of diagnostic laparoscopy alone likely are similar to those of gaining laparoscopic access, as mentioned in the "Complications of Access and Port Site Closure" section above. By comparison, a retrospective case series of 263 nonpalpable testes in 225 patients noted that 18% of the nonpalpable testes were actually palpable under anesthesia.[65] Of those who underwent diagnostic laparoscopy, 13.2% of cases were prevented from undergoing unnecessary abdominal exploration.

Despite smaller studies discounting the benefits of laparoscopy in obviating an inguinal exploration alone for the nonpalpable testis,[66] others have argued effectively that an

inguinal exploration alone can be inconclusive in as many as 66% of cases.[65] The treatment paradigm practiced at most institutions today is examination under anesthesia first, followed by diagnostic laparoscopy if the testes are still nonpalpable.

LAPAROSCOPIC ORCHIOPEXY

For those nonpalpable testes found to be intraabdominal, laparoscopic orchiopexy offers a viable and possibly preferred option to open abdominal exploration. The laparoscopic approach consists of three strategies: primary orchiopexy with preservation of the spermatic vessels; one-stage Fowler-Stephens orchiopexy with transection of the spermatic vessels and simultaneous transposition of the testicle down into the scrotum; and two-stage Fowler-Stephens orchiopexy with transection of the spermatic vessels and delayed transposition of the testicle down into the scrotum usually at least 6 months later. Of note, among these three laparoscopic approaches, there may be differences by indication, with primary laparoscopic orchiopexy used primarily for lower-lying intraabdominal testes and Fowler-Stephens approaches reserved for higher intraabdominal testes with severely limited mobility.

Various systematic reviews and meta-analyses have been performed comparing these three laparoscopic approaches to each other and to open approaches (Table 56.3). One of the first reviews analyzed 64 studies and found a pooled estimate of success of 74% for intraabdominal testes, regardless of technique.[67] Two-stage Fowler-Stephens approach had a pooled estimate of 77% success compared to 67% success for one-stage Fowler-Stephens approach and 81% for primary intraabdominal orchiopexy. The author did not comment on open versus laparoscopic approach, though it is likely all studies included in the older review reflected the open approach. A more contemporary systematic review and meta-analysis compared single-stage with two-stage Fowler-Stephens orchiopexies and included 61 studies, which included both open and laparoscopic techniques.[68] Of the subset of laparoscopic Fowler-Stephens orchiopexies, the pooled success rates were 83.4% and 88.8% for single-stage and two-stage approaches, respectively. Of note, the authors of the review found a much higher reporting of complications among the two-stage studies, with the most common complications being ileus, hematoma, and infections. Another recent systematic review found seven studies, most of which included laparoscopic approaches, comparing primary orchiopexy with Fowler-Stephens orchiopexy for intraabdominal testes, and noted higher success rates and lower atrophy rates with the former.[69] The authors point out, however, that confounding by indication may explain the difference, with primary orchiopexy being performed for lower-lying intraabdominal testes that have more favorable outcomes compared to higher-lying intraabdominal testes. A fourth systematic review compared open orchiopexy against laparoscopic orchiopexy for intraabdominal nonpalpable testes.[70] The authors had strict inclusion criteria and ultimately included sevn total studies in their review. No differences were seen with respect to operative time, success rate, atrophy rate, or recurrence, but length of stay was shorter in the laparoscopic group.

In conclusion, diagnostic laparoscopy is generally very safe and informative in cases of nonpalpable testes. If testes are located in the abdomen, laparoscopic instruments may be introduced to complete the orchiopexy safely and bring the testes down to the scrotum. If the spermatic vessels require division, then a staged laparoscopic Fowler-Stephens

Table 56.3 Pediatric Orchiopexy – Systematic Reviews/Meta-analyses

Reference	No. Studies	No. Testes	No. Success (%)	No. Atrophy (%)
Docimo (1995)[67]	64	2491	Inguinal 1388/1566 (88.6) 1-stage FS 214/321 (66.7) 2-stage FS 43/56 (76.8)	Inguinal 178/1566 (11.4) 1-stage FS 107/321 (33.3) 2-stage FS 13/56 (23.2)
Elyas (2010)*[68]	61	1405	1-stage FS 163/204 (80) 2-stage FS 638/751 (85) 1-stage laparoscopic FS 68/80 (83.4) 2-stage laparoscopic FS 419/467 (88.8)	Not assessed
Guo (2011)[70]	7	439	For nonpalpable testes: Laparoscopic orchiopexy 68/75 (90.6) Open orchiopexy 52/59 (88.1)	For nonpalpable testes: Laparoscopic orchiopexy 18/121 (14.9) Open orchiopexy 3/56 (5.4)
Wayne (2015)#[69]	7	N/A	No meta-analysis performed, but primary orchiopexy (mostly laparoscopic) 85–100% vs FS orchiopexy (mostly laparoscopic) 63–96%	Not assessed

FS, Fowler-Stephens
*Elyas et al. weighted studies to obtain pooled % success rates rather than simple additive success rates
#Wayne et al. only performed systematic review and did not pool estimates of success or failure due to heterogeneity of studies

Table 56.4 Laparoscopic Varicocelectomy – Systematic Reviews/Meta-analyses

Reference	No. Studies	No. Patients	Mean Age (yrs)	Recurrence Rate (%)	Postoperative Hydrocele Rate (%)
Borruto (2010)[72]	11	1443	14.6	Lap: 4.7 Open: 9.5	Lap: 9.5 Open: 6.7
Diegidio (2011)[73]	33	>5000	n/a (mostly adults)	Lap: 11.1 Microsurgical subinguinal: 2.1 Microsurgerical inguinal: 9.5 Palomo open: 12.5 Inguinal open: 15.7 Embolization: 4.3	Lap: 7.6 Microsurgical subinguinal: 0.7 Microsurgerical inguinal: 0.3 Palomo open: 7.6 Inguinal open: 7.5 Embolization: n/a

orchiopexy is preferable with higher success rates than a single-stage approach.

LAPAROSCOPIC VARICOCELECTOMY

The adolescent scrotal varicocele is commonly identified and typically a benign process. In select cases, however, the process may progressively impair spermatogenesis in the testicle and ultimately contribute to infertility. As such, certain adolescents with varicocele undergo repair if the condition causes chronic pain, contributes to testicular size differences, or is associated with abnormal semen parameters that may be used as a surrogate for future fertility potential. Currently, treatment options for varicocelectomy include open inguinal (Ivanessevich), high retroperitoneal (Palomo ligation of testicular artery and veins), subinguinal microscopic, laparoscopic (Palomo-like mass ligation or artery-sparing), and embolization or sclerotherapy approaches.[71] Each technique has its own advantages and disadvantages, with complications primarily including varicocele persistence or recurrence, hydrocele or hematoma formation, and testicular atrophy or loss (Table 56.4).

A recent systematic review and meta-analysis found 11 studies during a 10-year period specifically limited to adolescents that compared laparoscopic versus open techniques in varicocele repair.[72] Recurrence rates were 4.7% and 8.6%, and hydrocele formation rates were 9.5% and 6.7% for the laparoscopic and open groups, respectively (not significant). Another systematic review from the adult literature examined 33 studies and concluded that of all techniques mentioned above, the subinguinal microsurgical technique conferred the highest pregnancy rates with the lowest complications.[73] Laparoscopic varicocelectomy was examined in nine studies with a pooled pregnancy rate of 27.5%, pooled recurrence rate of 11.1%, and pooled hydrocele formation rate of 7.6%. Of note, scrotal subcutaneous emphysema and scrotal pain were complications reported only among the laparoscopic varicocelectomy patients. No cases of testicular atrophy were reported.

The laparoscopic varicocelectomy traditionally included ligation of both testicular veins and artery, but techniques have been described that spare the testicular artery due to concern for impaired spermatogenesis. One prospective study compared laparoscopic artery-sparing versus artery-ligating techniques in the same institution.[74] Overall, semen analyses showed significantly better parameters in the artery-sparing group. Of 63 patients in the artery-ligating group, eight developed postoperative hydrocele, compared with one among 59 patients in the artery-sparing group. However, varicocele persistence/recurrence was noted in six patients in the artery-sparing group compared to none in the artery-ligating group. Thus, sparing the testicular artery laparoscopically may decrease hydrocele risk but increase the possibility of failing to correct the varicocele, presumably due to missed testicular veins. It is important to note that those patients in whom the testicular artery is ligated should be counseled that their testicle may subsequently depend on blood supply from the deferential artery, and thus that future vasectomy could potentially further devascularize the testicle.

The laparoscopic varicocelectomy, then, is a viable MIS approach for correction of symptomatic varicoceles. Hydrocele formation may be higher compared to open nonmicrosurgical techniques, but recurrence rates seem to be lower. Artery-sparing techniques can improve semen quality, but carry the risk of varicocele persistence or recurrence.

LAPAROSCOPIC INGUINAL HERNIA REPAIR

Inguinal hernias occur in approximately 1–5% of children <18 years old. The risk of bowel incarceration is highest during infancy, but persists in older children. Traditionally, open inguinal exploration has been performed to find the hernia sac, careful separation from the cord structures must be carried out, and a high ligation of the hernia sac has performed at the level of the internal ring. Laparoscopic hernia repair has been studied as a viable alternative to the open inguinal approach, particularly when there is a question of a contralateral inguinal hernia.

A recent systematic review analyzed 53 studies that compared laparoscopic and open hernia repairs in children.[75] Conversion rates to open among those children who underwent laparoscopic inguinal hernia repairs ranged from 0% to 1.7%. Pooled estimates of hernia recurrence were no different between the laparoscopic cases (1.6%) and the open cases (1.4%). Among infants only, hernia recurrence and wound infections were higher among the open than among the laparoscopic cases. The authors of the systematic review pooled all other complications including hydrocele formation, wound infection, testicular atrophy, and iatrogenic cryptorchidism and noted a lower rate among laparoscopic cases (0.9%) compared to the open cases (2.7%). Another systematic review and meta-analysis with more stringent inclusion and exclusion criteria found three randomized controlled trials and four higher-quality observational studies that compared open and laparoscopic hernia repairs in children.[76] The authors found no differences in hernia recurrence, hydrocele formation, testicular

atrophy, or wound infection between the groups. Of note, while operative time was no different between the groups for unilateral hernia repair, among patients undergoing bilateral hernia repair, the laparoscopic group required significantly less operative time. Also, because laparoscopic hernia repair is performed in a transperitoneal manner, the approach carries additional risk of bowel or vascular injury and future intraabdominal adhesions.

The laparoscopic hernia repair appears to be safe, with acceptable success rates, though not widely implemented. The approach may be advantageous for older children with a concern for a contralateral inguinal hernia. The diagnostic laparoscopy at the beginning of the case may show whether the contralateral internal ring is open or closed, and the laparoscopic technique could then be utilized to close the defect if a contralateral hernia is present.

Conclusions

Indications for MIS in pediatric urology have expanded, particularly with the diffusion of robotic-assisted laparoscopy that allows more complex intracorporeal reconstruction. Pure laparoscopic surgeries retain a significant role in extirpative cases and those not requiring intracorporeal suturing, such as the laparoscopic orchiopexy, varicocelectomy, hernia repair, and simple nephrectomy. As a surgeon transitions from open surgery to MIS approaches, recalling the importance of visual cues where tactile feedback lacks, maintaining focus on atraumatic tissue handling, and exercising care and diligence during introduction and removal of working port trocars remain crucial. Knowledge of anatomy is essential, and the surgeon must be experienced with the key steps of each procedure that the carry highest risk to the patient.

With proper patient selection, MIS confers potential advantages over open surgery including smaller incisions, less postoperative pain, and shorter hospitalization while offering similar rates of surgical success. It is important here to restate that the implementation of MIS in pediatric urology marked an exciting, novel phase in clinical practice, but cumulative experience in the field – beyond a few high-volume centers – is still developing. It is incumbent upon practitioners to maintain focus on examining longer-term outcomes and develop robust multi-institutional efforts to confirm safety and efficacy. We expect the cycle of innovation and diffusion to continue, leading to advances in surgery that may not only potentially revolutionize operations, but also carry the promise of optimizing care of our patients.

References

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Chapter 56 Questions

1. Which of the following that happens to the pulmonary system during pneumoperitoneum >10 mm Hg is FALSE?
   a. Decreased functional residual capacity
   b. Decreased oxygen saturation
   c. Increased end-tidal carbon dioxide levels
   d. Improved pulmonary compliance
   e. Increased airway pressures

2. Which of the following is TRUE about comparisons of techniques for gaining laparoscopic access?
   a. Hasson technique has highest risk of vascular injury
   b. Veress technique has the lowest risk of subcutaneous emphysema
   c. No technique has been shown to be superior to the others
   d. Optical trocar entry has the highest risk of bowel injury
   e. Modified Veress technique carries zero risk of bowel or vascular injury since fascia is tented up

3. Which of the following is FALSE regarding pyeloplasty outcomes?
   a. Robotic-assisted laparoscopic approaches have shorter operative time than pure laparoscopic approaches
   b. Retroperitoneoscopic pyeloplasty has significantly worse outcomes than transperitoneal approaches
   c. Success rates across open and minimally invasive approaches are all >95%
   d. Possible complications of pyeloplasty include urine leak, ileus, and rare bowel injuries
   e. Increasing percentage of pyeloplasties are being performed with robotic-assisted laparoscopic approaches

4. Which of the following is a complication unique to heminephrectomy compared to simple total nephrectomy?
   a. Port site hernia
   b. Urinoma formation
   c. Bowel injury
   d. Vascular injury
   e. Hematoma

5. Which of the following is FALSE about treatment of vesicoureteral reflux?
   a. Robotic-assisted laparoscopic ureteral reimplantation usually has shorter hospital stay compared to open techniques
   b. The patient population under reimplantation has changed now compared to 20 years ago
   c. Bladder leak through trocar sites is a major complication of intravesical minimally invasive laparoscopic ureteral reimplantation
   d. Robotic-assisted laparoscopic ureteral reimplantation can be performed only in extravesical fashion
   e. Urinary retention is a complication especially following bilateral extravesical reimplantation

6. Which of the following is FALSE about ureteroureterostomy?
   a. The ureteral stent is usually placed into the recipient ureter and collecting system
   b. The "yo-yo" effect is worrisome for causing pyelonephritis in the "bad" moiety
   c. Ureteroureterostomy provides a viable alternative in duplex renal anomalies compared to heminephrectomy
   d. Success rates of minimally invasive laparoscopic ureteroureterostomy are not significantly different from open ureteroureterostomy
   e. Complication rates of minimally invasive laparoscopic ureteroureterostomy are not significantly different from open ureteroureterostomy

7. Which of the following is FALSE regarding robotic-assisted laparoscopic appendicovesicostomy?
   a. The continence mechanism is based on the Mitrofanoff principle
   b. Robotic-assisted laparoscopic appendicovesicostomy has much higher success rates than open appendicovesicostomy
   c. Longer follow-up is needed with the minimally invasive laparoscopic approach
   d. Stomal stenosis and urinary incontinence are complications of appendicovesicostomy
   e. Secondary surgeries may be necessary if internal hernias occur following appendicovesicostomy and cause small bowel obstruction

8. Which of the following is TRUE regarding diagnostic laparoscopy?
   a. Vanished testes are marked by blind-ending vas but normal-appearing spermatic vessels
   b. Diagnostic laparoscopy is poor at accurately localizing nonpalpable testes
   c. Inguinal exploration first before diagnostic laparoscopy for nonpalpable testes may be inconclusive in up to 66% of cases
   d. Up to 50% of nonpalpable testes may be actually palpable under anesthesia
   e. Preperitoneal insufflation is not a possible complication of diagnostic laparoscopy

9. Which of the following is FALSE regarding laparoscopic varicocelectomy?
   a. Laparoscopic varicocelectomy is very similar to the open Ivanessevich repair
   b. Varicocele recurrence rates following laparoscopic varicocelectomy range from 4% to11%
   c. Hydrocele formation rates following laparoscopic varicocelectomy range from 8% to 10%
   d. Unique complications of laparoscopic varicocelectomy include scrotal subcutaneous emphysema and scrotal pain
   e. Artery-sparing techniques of laparoscopic varicocelectomy have been associated with improved

semen parameters but higher risk of varicocele recurrence/persistence

10. Which of the following is FALSE regarding laparoscopic inguinal hernia repair?
    a. Hernia recurrence rates are no different between laparoscopic and open inguinal hernia repairs
    b. Complication rates of laparoscopic inguinal hernia repair are not significantly different and may possibly be lower than those of open inguinal repair
    c. Transperitoneal laparoscopic inguinal hernia repair carries the risk of bowel or vascular injury
    d. Laparoscopic hernia repair allows examination and repair of a contralateral hernia if one is suspected
    e. Laparoscopic inguinal hernia repair may only be done safely in children age 10 or older

Case Studies

CASE 1

A 7-month-old boy presents to your office for evaluation of a unilateral undescended testicle. You cannot palpate the left testicle in clinic. The patient is otherwise healthy and is developing well.

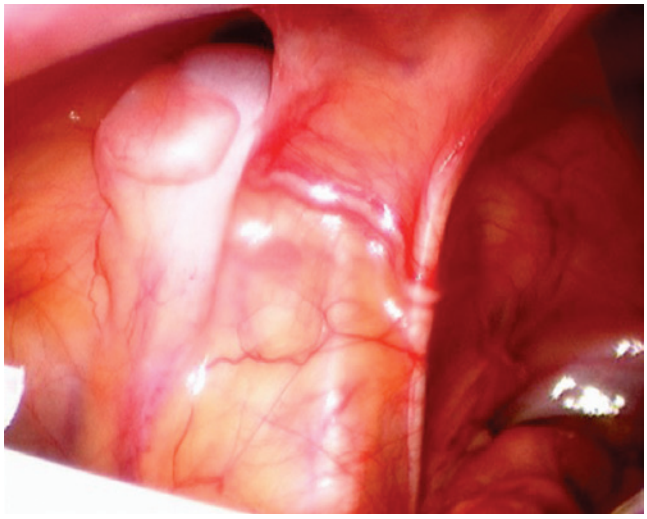
1. What is the next best step in localizing the nonpalpable testis?
    a. Ultrasound of the abdomen and groin
    b. MRI of the abdomen and pelvis
    c. Unilateral groin exploration in the OR
    d. Diagnostic laparoscopy in the OR
    e. Examination under anesthesia in the OR

2. If the examination under anesthesia in the OR does not reveal a palpable testicle, what is the next step?
    a. Ultrasound of the abdomen and groin
    b. MRI of the abdomen and pelvis
    c. Unilateral groin exploration in the OR
    d. Diagnostic laparoscopy in the OR
    e. Laparotomy

3. If diagnostic laparoscopy reveals the testicle located in the abdomen next to the internal ring (Case Fig. 56.1), which of the following is the LEAST logical next step?
    a. Open inguinal exploration and primary orchiopexy
    b. Open first-stage Fowler-Stephens orchiopexy
    c. Laparoscopic primary orchiopexy
    d. Laparoscopic single-stage Fowler-Stephens orchiopexy
    e. Laparoscopic first-stage Fowler-Stephens orchiopexy

CASE 2

During the workup for recurrent RIGHT flank pain, an 8-year-old girl was diagnosed with complete duplication of the RIGHT collecting system, an ectopic upper pole moiety ureter, and upper pole urinary tract dilation (Case Fig. 56.2). The child is normal sized and otherwise healthy. Voiding cystourethrogram showed no vesicoureteral reflux. Differential renal function showed 10% function in the RIGHT kidney upper moiety, 30% function in the RIGHT kidney lower moiety, and 60% function in the LEFT kidney.



Case Figure 56.1



Case Figure 56.2

1. What is the most reasonable next step in the management of this child?
    a. Observation
    b. Open RIGHT upper pole moiety heminephrectomy
    c. Minimally invasive RIGHT upper pole moiety heminephrectomy
    d. Common-sheath ureteral reimplantation of both RIGHT ureters
    e. Minimally invasive RIGHT upper-to-lower ipsilateral ureteroureterostomy

2. A robotic-assisted laparoscopic ipsilateral ureteroureterostomy is chosen as the procedure. Before access is obtained in the OR, what is the first step?

a. Cystoscopic retrograde insertion of ureteral stent into the upper pole ureter
b. Cystoscopic retrograde insertion of ureteral stent into the lower pole ureter
c. Percutaneous antegrade insertion of ureteral stent down the upper pole ureter
d. Percutaneous antegrade insertion of ureteral stent down the lower pole ureter
e. On-table voiding cystourethrogram

3. During access, the first attempt of Veress insertion causes subcutaneous emphysema. The second attempt is advanced deeper in the same location and blood is aspirated. What vessel has been punctured and what is the next best step?
   a. Left common iliac vein – remove the Veress needle and abort the procedure
   b. Left common iliac vein – leave the needle in place and explore either open or laparoscopically via other location
   c. Right common iliac artery – remove the Veress needle and abort the procedure
   d. Right common iliac artery – leave the needle in place and explore either open or laparoscopically via other location
   e. Inferior vena cava – insert a laparoscope in another location and repair laparoscopically

Answers

1. **d.** Compliance decreases with pneumoperitoneum. All the remaining answers are TRUE. Hypoxemia, hypercarbia, and barotrauma are all risks of increased pneumoperitoneum.
2. **c.** A Cochrane review of 13 various techniques for gaining access showed no superior single technique.
3. **b.** In a recent meta-analysis, retroperitoneoscopic pyeloplasty had no significantly different success rates than transperitoneal laparoscopic approaches with similar complication rates.
4. **b.** Urinomas may form from unrecognized injury to the collecting system of the remaining moiety or leaving functional parenchyma of the excised moiety. All other complications may occur with either hemine-phrectomy or simple total nephrectomy.
5. **d.** Robotic-assisted laparoscopic ureteral reimplantation can be performed in either an extravesical or an intravesical manner.
6. **b.** The "yo-yo" effect where urine from the "bad" moiety refluxes up the recipient ureter is worrisome for causing infection in the "good" recipient renal moiety.
7. **b.** Robotic-assisted laparoscopic and open appendicovesicostomies appear to have equivalent success rates. The types of complications appear to differ.
8. **c.** Vanished testes are marked by blind-ending vessels. Diagnostic laparoscopy is excellent at localizing nonpalpable testes. Roughly 18% of nonpalpable testes may be actually palpable under anesthesia. Lastly, preperitoneal insufflation is a possible complication of access and thereby diagnostic laparoscopy.
9. **a.** Laparoscopic varicocelectomy is similar to the Palomo repair, not the Ivanessevich repair.
10. **e.** Laparoscopic hernia repair has been safely and successfully performed in children as young as infants and is not restricted by age alone.

CASE 1

1. **e.** Studies have suggested that a substantial portion of nonpalpable testes may actually be palpated under anesthesia, which would guide surgical management to either diagnostic laparoscopy or inguinal exploration next under the same anesthetic.
2. **d.** Diagnostic laparoscopy provides excellent localization of nonpalpable testes. It can identify viable intra-abdominal testes, presence or absence of blind-ending spermatic vessels or vas, and any question of contralateral hernia.
3. **d.** Given the relatively low-lying intraabdominal/inguinal location of the testicle, any of the options are feasible and logical, except for a single-stage Fowler-Stephens orchiopexy. If division of the spermatic vessels is needed to allow the testicle to reach the scrotum, then a staged approach is preferable to a single-stage, given the better success rates and lower atrophy rates.

CASE 2

1. **e.** Given some preserved renal function in the upper moiety, an ipsilateral ureteroureterostomy is preferable over a heminephrectomy. Ureteral reimplantation of both ureters, in the absence of vesicoureteral reflux, may put the lower pole moiety ureter at risk.
2. **b.** The recipient ureter is usually prestented before the anastomosis is performed to "protect" the functional "good" renal moiety. No repeat VCUG is needed as one was done preoperatively.
3. **d.** The most common vessel that is injured during access is the right common iliac artery. Since it is arterial, the needle should be kept in place. The injury should then be explored via either conversion to open surgery or via insertion of a laparoscope in another location.

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57 Complications of Surgery for Posterior Urethral Valves

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CHAPTER OUTLINE

In Utero Intervention
Outcomes
Initial Management of Patients With Posterior Urethral Valves
Primary Valve Ablation
Alternatives to Valve Ablation: Cutaneous Vesicostomy and Upper Tract Diversion
Controversies in Initial Management of Posterior Urethral Valves
Prognosis Following Initial Therapy
Vesicostomy Closure
Vesicoureteral Reflux
Bladder Dysfunction
Delayed Presentation of Posterior Urethral Valves
Progression to End-stage Renal Disease and Renal Transplantation
Conclusions
Chapter 57 Questions and Answers

KEY POINTS

1. Posterior urethral valves (PUV) usually are diagnosed during antenatal sonographic screening, but some patients present in infancy with an abdominal mass, failure to thrive, urosepsis, or urinary ascites, and a minority present following toilet training.
2. Antenatal intervention is considered for bilateral hydroureteronephrosis and a distended bladder when hypotonic electrolytes are found on serial vesicocenteses.
3. A voiding cystourethrogram is the gold standard for diagnosing PUV.
4. Renal function is determined postnatally by monitoring the change in the serum creatinine level following bladder decompression.
5. Primary valve ablation is the treatment of choice when the urinary tract decompresses and renal function improves with catheter drainage.
6. A serum creatinine concentration <0.8 mg/dL 1 month following initial treatment or at 1 year of age is associated with favorable renal function.
7. Hydronephrosis may be chronic as a result of reflux, incomplete bladder emptying, and/or poor detrusor compliance.
8. Bladder dysfunction is manifested primarily by detrusor overactivity and incomplete bladder emptying.
9. Pop-off mechanisms, including posterior urethral valves, unilateral vesicoureteral reflux and renal dysplasia (VURD) syndrome, bladder diverticulum, patent urachus, and urinomas, are thought to protect the bladder, but might not protect long-term renal function.
10. Delayed presentation of PUV should be considered in boys >5 years old who present with diurnal incontinence, urinary tract infection, voiding pain, or urinary frequency.
11. In boys with a history of PUV, graft survival and serum creatinine following renal transplant are similar to patients without bladder outlet obstruction, because meticulous attention is paid to the management of lower urinary tract dysfunction.

Posterior urethral valves (PUV) occur in 1/8000 boys and are the most common form of obstructive uropathy causing end-stage renal disease (ESRD) in children, ultimately occurring in as many as 40% with PUV. In addition, PUV are associated with vesicoureteral reflux (VUR), pyelonephritis, overactive bladder, underactive bladder, polyuria, and incontinence.

The management of PUV has evolved since the late 1990s. With antenatal diagnosis and in utero intervention, the spectrum of the problems associated with this anomaly poses new challenges to the neonatologist, pediatric urologist, pediatric nephrologist, and transplant surgeon. Despite these advances, some children present in childhood or adolescence with subtle findings often overlooked during routine pediatric care. This chapter addresses complications of in utero intervention, urethral valve ablation, ureteral tailoring and reimplantation, and delayed presentation.

The evaluation and treatment of bladder dysfunction are also reviewed because this condition directly affects the success of ureteral surgery and kidney transplantation and dictates the need for augmentation cystoplasty.

In Utero Intervention

Since the mid-1980s, surgeons have been cautiously optimistic about the role of antenatal bladder decompression for obstructive uropathy and oligohydramnios.[1] The purpose of this intervention is to restore the amniotic fluid to a more normal volume and thereby prevent pulmonary hypoplasia, which is the pulmonary complication of oligohydramnios. Techniques used include vesicoamniotic shunt placement and cutaneous vesicostomy through hysterotomy.

Moderate enthusiasm for this new technology was generated following a report by Manning and associates[2] of the International Fetal Surgery Registry that suggested that fetal intervention resulted in survival of <44% of cases with oligohydramnios. However, a careful review of all reported cases of fetal intervention for suspected obstructive uropathy yielded only two documented cases in which antenatal bladder drainage could have improved the outcome.[3] More recently, refinements in the technology and better criteria for intervention have allowed the diagnosis and appropriate selection of candidates who may benefit from in utero therapy.[4,5]

Although fetal sonographic techniques have improved, in some cases, upper urinary tract changes that result from PUV are not apparent before 24 weeks of gestation.

Fetuses with PUV and normal-appearing anatomic features at 20 weeks of gestation are more likely to have normal renal function than those with severe early hydronephrosis. Consequently, antenatal therapy probably would not be beneficial in this group with a better prognosis.[6] A structural ultrasound scan performed at 20 weeks permits systematic evaluation of the urinary tract. The kidneys appear echodense in most cases. Large kidneys with mild parenchymal changes are seen in early obstruction, whereas small kidneys suggest significant parenchymal damage. Discrete focal cysts are a common sonographic manifestation of renal dysplasia.[5,7–13]

The ureters are assessed for dilation. Abnormal patency and dilatation of the ureterovesical junction (UVJ) suggest advanced urinary tract changes with poor prognosis. Bladder distention is almost always noted, and the classic "keyhole" sign is observed at times (Fig. 57.1). Bladder wall thickening also should be characterized. Symmetric thickening suggests PUV, whereas asymmetric thickening of the lower half of the bladder relative to the dome region suggests the prune belly syndrome.[4,10–13]

Because oligohydramnios can be present on the initial examination, amniotic infusion with warm lactated Ringer solution restores the amniotic fluid volume for antenatal sonographic surveillance.[5] The incidence of chorioamnionitis has been reduced by the routine administration of parenteral antibiotic therapy at the time of the infusion followed by 10 days of oral antibiotics. Fetal karyotyping is performed with chorionic villous sampling or cordocentesis to rule out aneuploidy and to confirm the fetal sex. Knowledge of the sex of the fetus is important because shunting of dilated urinary systems in patients who were later found to be female with cloacal malformations provides no benefit in this setting.[5]

Another important selection criterion for antenatal intervention is electrolyte determination on serial vesicocentesis performed at 48- to 72-hour intervals.[5,13–15] Normally, fetal urine is hypotonic, whereas urine in renal dysplasia is more likely to be isotonic.[13] Normal fetal urine has a sodium concentration <100 mEq/L, chloride concentration <90 mEq/L, and osmolality <210 mOsm/L. Analysis of fetal urine aspirated from the bladder allows analysis of fetal renal function; urine with normal electrolyte values suggests that fetal renal function will be adequate following bladder decompression. The other important parameter to measure is urinary β_2-microglobulin; levels >10 mg/L are highly suggestive of irreversible renal dysplasia.[16] Abnormal fetal urinary values on a single bladder aspiration may be misleading because this value may represent stale urine.[17] Instead, sequential aspiration is more reliable. If the fetal urine parameters improve to normal values, fetal renal function following urinary tract decompression may be acceptable. Using serial vesicocentesis, Freedman et al. reported a 60% survival and a 33% incidence of renal failure in high-risk fetuses identified in the first trimester with severe bilateral hydroureteronephrosis, bladder distention, and oligohydramnios.[18]

Although percutaneous vesicoamniotic shunts have been used for nearly 3 decades, these shunts have significant limitations.[2,3] Vesicoamniotic shunts become obstructed or displaced in 25% of cases, a situation necessitating additional procedures that can cause increased morbidity in the mother and the fetus, with a 5% procedure-related fetal loss rate.[5] The shunt provides only palliative therapy and does not treat the anomaly or the pulmonary hypoplasia and renal dysplasia that are responsible for up to half of the deaths in patients with PUV.

Despite the advances of the Rodeck shunt, which places the proximal and distal pigtails at 90-degree angles, shunt displacement occurs in 25–30% of cases.[19,20] The site of shunt placement is important. The shunt must avoid the dome and be positioned in the midline just above the pubic symphysis. Even when no problems with shunt placement and function are noted in the appropriate candidate, unusual and unexpected outcomes can occur. For example, even with appropriate selection criteria and shunt placement, some fetuses have persistent oligohydramnios that leads to fetal demise. These fetuses typically have small kidneys with significant fibrocystic dysplastic changes suggesting progressive degeneration despite successful intervention.

The first reports of percutaneous fetal cystoscopy at 19 weeks and subsequent endoscopic fulguration of the valves were published in 1995.[1,21] At the time of the initial vesicocentesis, a 0.7-mm fiberoptic endoscope was threaded through the lumen of an 18-gauge thin-walled needle, similar to the technique used to perform transabdominal embryofetoscopy. At 22 weeks' gestation, a 10-gauge trocar was inserted through the maternal abdomen and into the fetal bladder. A 2.5-mm steerable endoscope with a 1.3-mm operating channel was passed through the trocar. A soft-tip 0.025-inch guidewire was used and the endoscope was advanced along the wire. The valves were electrocauterized with a 2Fr ball-tip monopolar flexible electrode with 25 W

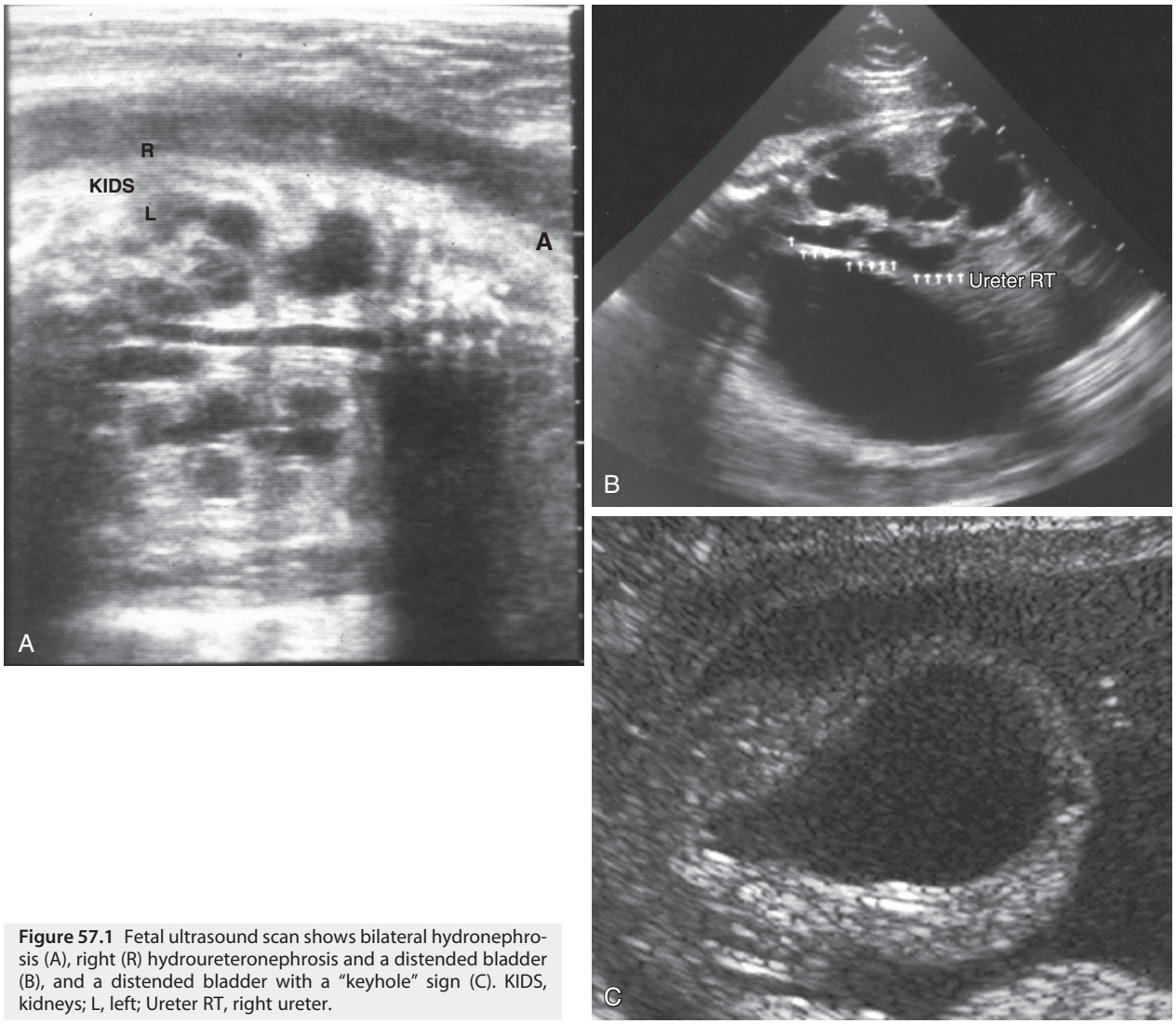


Figure 57.1 Fetal ultrasound scan shows bilateral hydronephrosis (A), right (R) hydroureteronephrosis and a distended bladder (B), and a distended bladder with a "keyhole" sign (C). KIDS, kidneys; L, left; Ureter RT, right ureter.

of coagulating current. Following the 2-hour procedure, improvement in the urinary tract dilation with restoration of the amniotic fluid was seen on the posttreatment ultrasound scan. Delivery occurred at 31 weeks as a result of preterm labor, and the infant had a postnatal diagnosis of PUV. The remaining patients had prune belly syndrome or were females with urethral atresia or urogenital sinus anomalies. All fetuses underwent karyotyping and serial vesicocentesis for electrolytes, and those with PUV had favorable electrolyte values. Intervention was performed at a weight of 2000 g, with Apgar score of 5 and 7.[5] A 10-mm abdominal wall defect with minor omental herniation was present at the site of the trocar. The infant died of pulmonary hypoplasia on day 4 of life.

More recently, Martinez et al. reported fetal cystoscopic diode laser ablation of PUV in 20 fetuses at a mean gestational age of 18.1 weeks.[22] The median operative time was 24 minutes. Access to the urethra was obtained in 95% and normalization of amniotic fluid and bladder size occurred in 80%. In follow-up, termination of pregnancy occurred in 45%, 73% had "normal" renal function, and 27% had end-stage renal disease (ESRD) and were awaiting transplantation.

OUTCOMES

Holmes and colleagues reviewed the University of California San Francisco experience with fetal intervention for obstructive uropathy over 2 decades.[23] They evaluated 40 patients, and 36 fetuses underwent surgical intervention. Mean gestational age at intervention was 22.5 weeks. The fetuses underwent various in utero surgical procedures including cutaneous ureterostomies (one), fetal bladder marsupialization (two), in utero valve ablation (two), and placement of a vesicoamniotic catheter (nine). One patient who underwent valve ablation subsequently required a vesicoamniotic shunt for significant ascites. Another patient required multiple shunt placements as a result of malfunction or migration of the shunt. Before delivery, fetal demise occurred in 43%. One pregnancy was electively terminated because of significant pulmonary hypoplasia, and the remaining deaths resulted from prematurity

and respiratory failure. Long-term follow-up (mean 11.6 years) in five of eight living patients revealed that 63% had chronic renal insufficiency (mean serum creatinine, 2.5 mg/dL after 1 year of age). Two patients required renal transplantation. Five of the eight living patients underwent urinary diversion (vesicostomy or cutaneous ureterostomy) or augmentation cystoplasty. This study underscores the finding that intervention often does not prevent ESRD, despite "favorable" fetal renal function, and suggests that intervention may primarily assist in keeping the fetus viable to term.

Biard and colleagues reported their long-term outcomes in 7 of 18 boys with PUV treated by vesicoamniotic shunting.[24] Other diagnoses included urethral atresia (four) and prune belly syndrome (seven). These investigators followed their algorithm for antenatal evaluation including fetal karyotyping and serial vesicocentesis for electrolytes and management.[24] Parents requested shunting in three cases with poor predicted prognoses. Most cases (13 of 18) had good prognostic findings. The mean gestational age at first vesicocentesis was 19.8 weeks and at vesicoamniotic shunting was 21.9 weeks. Eight complications were associated with vesicoamniotic shunting including shunt displacement in five (requiring replacement in four), abdominal omental herniation in two, and premature rupture of membranes 4 days following shunt placement in one. Mean gestational age at delivery was 34.6 weeks. In boys with PUV, long-term renal function was acceptable (creatinine clearance >70 mL/minute) in three of seven. Mild renal insufficiency was defined as creatinine clearance <70 mL/minute not requiring renal replacement therapy and was found in three of seven. Only one of seven required renal transplantation at 10 years of age. Five patients voided spontaneously, one required catheterization, and one voided spontaneously and was also catheterized. In the overall group of children who underwent shunting, normal physical and cognitive development was noted in 78%.

In a recent retrospective case-controlled analysis of 111 fetuses comparing vesicoamniotic shunting to fetal cystoscopy/valve ablation and no intervention, both shunting and fetal cystoscopy improved survival at 6 months, and fetal cystoscopy was more likely to prevent impairment of renal function than was shunting.[25] A prospective randomized controlled trial comparing the effectiveness of these two interventions for severe lower urinary tract obstruction was recommended.

Initial Management of Patients With Posterior Urethral Valves

The newborn with PUV may have an abdominal mass (49%), failure to thrive (10%), urosepsis (8%), or urinary ascites (7%).[26] In most cases, antenatal sonography demonstrates bilateral hydroureteronephrosis and a distended bladder (Fig. 57.2). When the bladder is empty, one often feels or palpates a walnut-size, firm mass in the pelvis that corresponds to the trabeculated bladder muscle. In addition, dyspnea associated with pneumothorax or pneumomediastinum may be the initial sign of severe urethral obstruction.[27] A normal urinary stream is an infrequent finding.[26]

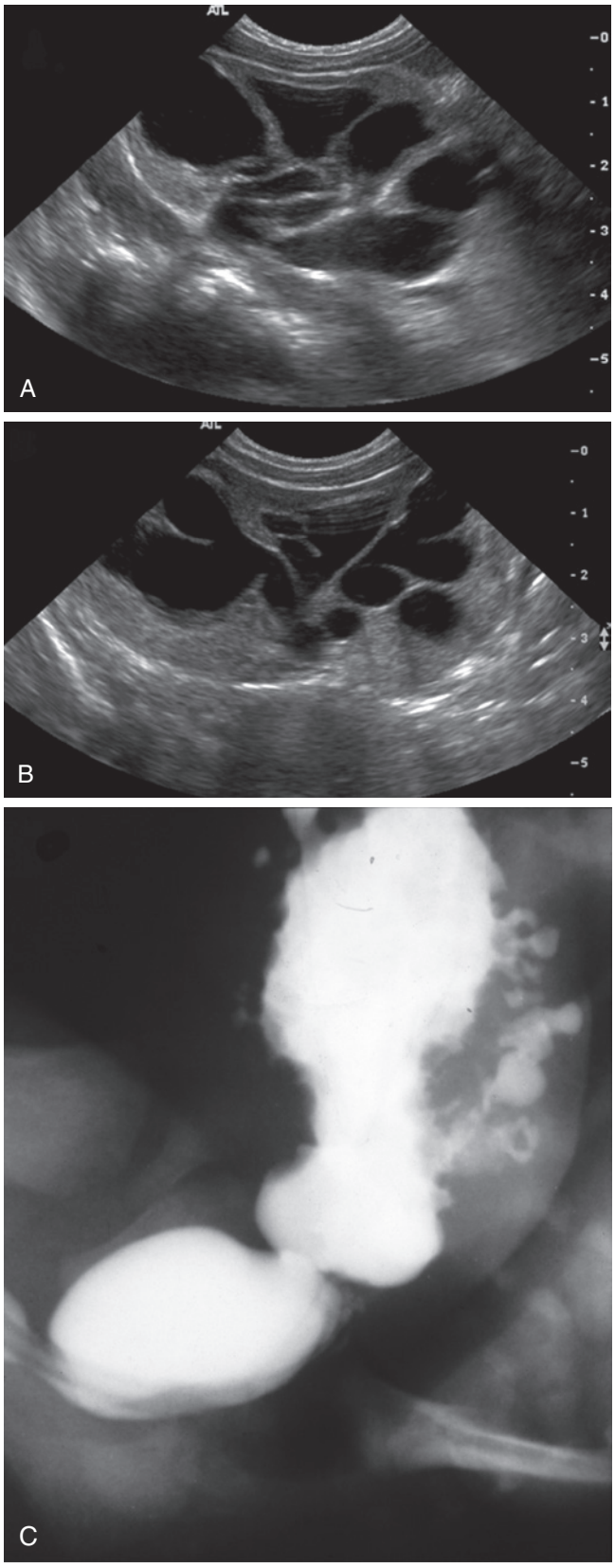


Figure 57.2 Renal ultrasound scan shows severe right hydronephrosis and hydroureter (A), severe left hydronephrosis (B), and voiding cystourethrogram demonstrating typical findings of type I posterior urethral valves (C).

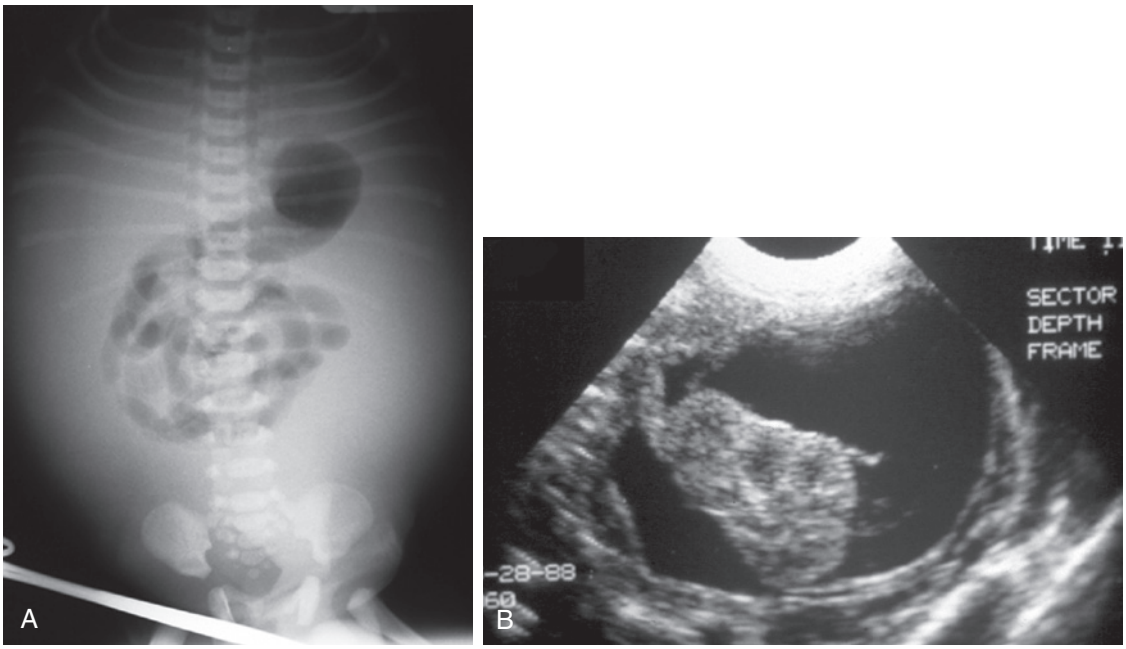


Figure 57.3 Newborn with an abdominal mass. A, Abdominal plain film shows the ground-glass appearance of abdominal ascites. B, Renal ultrasound scan demonstrates an extracapsular urinoma and complete decompression of the collecting system.

A voiding cystourethrogram (VCUG) should be obtained promptly to establish the correct diagnosis (see Fig. 57.2C). Sonography usually shows significant bilateral hydronephrosis with a thick bladder. Demonstration of the corticomedullary junction is a favorable prognostic sign for renal function. Conversely, echogenic kidneys, subcortical cysts, and failure to demonstrate the corticomedullary junction on the initial and follow-up ultrasound studies are unfavorable signs.[10,12,26]

Antenatal urinomas are thought to serve as a protective mechanism to reduce pressure-related impairment of renal function (Fig. 57.3). Patil and colleagues studied two groups of patients with PUV.[28] Group 1 had ascites with and without urinoma and no vesicoureteral reflux (VUR), and group 2 had urinoma formation alone (unilateral or bilateral) and bilateral VUR. Moderate renal failure was seen in the three boys with ascites alone, and mild renal failure was present in the three boys with urinoma and ascites. The investigators speculated that ascites without urinoma suggests bladder rupture and more severe renal damage. The three boys in group 2 with bilateral urinomas had normal glomerular filtration rates (GFRs), whereas the nine boys with unilateral urinomas showed impaired renal function on the side of the urinoma. These findings were confirmed in a more recent study of 89 boys with PUV, of whom nine had a urinoma.[29] The nadir creatinine (Cr) was significantly lower in boys with urinomas compared with unaffected boys, and none with a urinoma had ESRD or underwent renal transplantation.

Patil and colleagues hypothesized that if renal extravasation is extracapsular, it could have a protective effect on renal function, whereas if the extravasation is subcapsular, the renal parenchyma is compressed, thus possibly leading to the deleterious effects of a urinoma.[28] If the type of urinoma cannot be determined, this may explain the results of other studies that showed no association between renal function and urinoma formation.[30]

The initial treatment for neonates with suspected PUV is directed at decompressing the urinary tract with a small transurethral feeding tube. Attention is given to pulmonary function and fluid and electrolyte management. We recommend passing the catheter at the time of the first ultrasound scan immediately following birth. The catheter can be difficult to pass because of the dilated posterior urethra and the bladder neck hypertrophy. Sonography confirms the placement of the catheter within the bladder because a catheter that is coiled in the posterior urethra will cause the majority of urine to drain around the catheter. Similarly, if too much of the catheter is coiled in the bladder, the tip may extend distally through the external sphincter and provide some drainage of the bladder with continuous leakage around the catheter. Foley catheter use is discouraged because the balloon can obstruct the ureteral orifices when the thick-walled bladder is decompressed, or it can cause severe bladder spasm that can obstruct the intramural ureters. Although anuria can result from the noncompliant, hypertonic bladder wall and can lead to relative obstruction of the UVJ, mechanical occlusion can also be the source of anuria in some cases.[31]

A recent novel approach for temporary bladder decompression was described using a 6Fr 12-cm double J stent advanced over a guidewire.[32] In 30 patients, the mean peak serum Cr diminished from 2.23 mg/dL to 0.56 mg/dL, and the investigators also demonstrated that the stent drained the bladder significantly more efficiently than did either a feeding tube or Foley catheter.

Antibiotic prophylaxis is commonly prescribed. In the absence of suspected sepsis, ampicillin or cephalexin is administered at the time of catheter placement.[26] It is best to avoid nephrotoxic agents that may cause further tubular

dysfunction. Finally, neonatal circumcision should be recommended in these boys because it significantly reduces the risk of urinary tract infection (UTI).[33]

PRIMARY VALVE ABLATION

Infant urethral sounds should be passed to calibrate the urethra. The term newborn male urethra generally accepts an 8Fr endoscope. Dilation of the urethra to pass a larger instrument may lead to urethral trauma and stricture formation. Vigorous dilation may result in iatrogenic hypospadias due to splitting of the glans to the subcoronal level. Vesicostomy is the treatment alternative for the infant whose urethra is too small to accept an endoscope.[26]

Smith and colleagues reported valve ablation using the 6.9Fr cystoscope and the 3Fr Bugbee electrode in premature infants as small as 2500 g.[34] The coagulating current was used to ablate the valves. However, we advocate using a small Bugbee electrode using low cutting current. In older patients, the 11- or 13Fr Storz resectoscope can be used with the cutting current and the right-angle loop. In addition, the neodymium:yttrium-aluminum-garnet (Nd:YAG) or holmium:YAG laser may be used.[35,36] The Nd:YAG laser was successful in 16 of 20 patients, and four patients underwent repeat valve ablation.[35] In contrast, the holmium:YAG laser was reported to result in improved success in voiding after catheter removal, reduced need for repeat valve ablation, and a lower risk of urethral stricture compared with electrofulguration.[36]

Varying methods are used to ablate PUV. The valves should be incised at the 12-o'clock position and the lateral leaflets should be cut at the 5- and 7-o'clock positions.[37] Passing a cystoscope or resectoscope that is too large may result in urethral stricture.[38] Chertin and colleagues reported a series of 35 cases of valve ablation under fluoroscopic guidance using a 4Fr Fogarty balloon catheter filled with 0.5 mL of saline.[39] A postoperative VCUG revealed no residual valve in 34 of 35 patients (97%). Other methods include creation of a temporary perineal urethrostomy into which the cystoscope or resectoscope is passed or performance of the procedure in an antegrade fashion through a percutaneous cystostomy.[40]

A small feeding tube is left indwelling for 1 to 2 days, and a VCUG may be obtained at the time of catheter removal. If the VCUG is not obtained before discharge from the hospital, it should be obtained 2 to 4 weeks postoperatively to confirm satisfactory valve ablation. In addition, a renal sonogram assesses hydronephrosis and confirms satisfactory bladder emptying.

Another method to assess adequacy of valve ablation is the preoperative and postoperative urethral ratio.[41] This ratio is determined by measuring the diameter of the posterior urethra transversely at a point halfway between the bladder neck and the distal end of the membranous urethra and the diameter of the anterior urethra at the transverse diameter at the point of the maximum distention in the bulbar urethra. Measurements are most accurate on voiding films in which the catheter has been removed (Fig. 57.4). In one study,[41] the median urethral ratio before ablation was 8.6 (range 4–14.7) and that of normal age-matched controls was 2.6 (range 1.3–5.5). The postoperative urethral ratio was 3.1 (range 1.9–4). A second group of patients with a postoperative urethral ratio of 8 (range 5–15.5) after the first ablation underwent a second ablation with a final urethral ratio of 3.1 (range 2.9-6.4).[41] Valve ablation is successful in > 90% of patients. Long-term stricture formation is uncommon.[38]

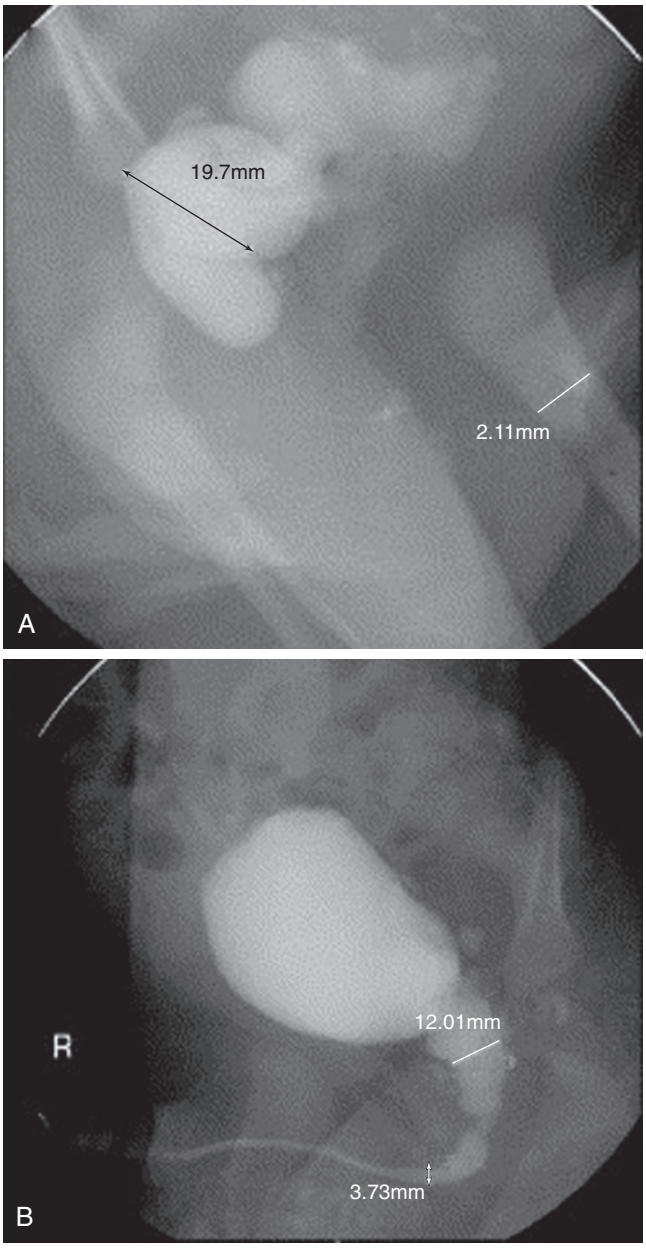


Figure 57.4 Posterior urethral measurements to determine the urethral ratio on a preoperative (A) and postoperative (B) voiding cystourethrogram. (With permission from Bani Hani O, Prelog K, Smith GHH. A method to assess posterior urethral valve ablation. *J Urol.* 2006;176:303-5.)

ALTERNATIVES TO VALVE ABLATION: CUTANEOUS VESICOSTOMY AND UPPER TRACT DIVERSION

An alternative to primary valve ablation is the creation of a temporary cutaneous vesicostomy.[42,43] A small transverse incision is made midway between the umbilicus and the pubic symphysis, and the dome of the bladder is brought

to the skin. If the anterior bladder wall rather than the dome is exteriorized, prolapse may occur. The vesicostomy should calibrate to 24–26Fr to avoid stenosis. In addition, daily dilation of the stoma with a plastic medicine dropper helps minimize contraction of the stoma. The vesicostomy drains into the diaper, and no urinary collection device is necessary.

Cutaneous vesicostomy has been shown to be as effective as valve ablation for initial therapy.[44] This form of management allows the bladder to cycle with voiding at low pressure through the stoma and does not reduce bladder capacity. A cutaneous vesicostomy should not be performed in the presence of active UTI because contraction of the bladder may occur. These babies should be maintained on antibiotic prophylaxis. In some cases, breakthrough febrile UTIs occur and vesicostomy closure is necessary.

In the past, proximal high diversion with cutaneous pyelostomy or cutaneous ureterostomy was advocated for neonates and infants with severe hydronephrosis and a persistently elevated creatinine concentration following catheter drainage.[26,45] Proximal diversion also provides the opportunity to perform renal biopsy, which may help predict the child's ultimate renal outcome. The problem with initial high bilateral proximal diversion is that urine is diverted away from the bladder, and this situation may result in a small contracted bladder that does not grow over time.[46]

In boys with PUV, UVJ obstruction usually occurs only during bladder filling and results from elevated intravesical pressure, rarely from obstruction secondary to detrusor hypertrophy. Furthermore, proximal high diversion therapy has not been shown to prevent ESRD because >85% of these patients have renal dysplasia.[47] In addition, by diverting the urine away from the bladder, regular cyclic vesical contraction may not occur and result in a smaller, less compliant bladder compared with vesicostomy.[46] Finally, cutaneous pyelostomies require placement of a diaper across the abdomen and flank, and even then the child's clothes may become wet. Consequently, this form of diversion generally is reserved for rare cases in which valve ablation or vesicostomy has failed to show improvement in upper urinary tract drainage or when urosepsis is secondary to pyonephrosis.[26,45]

An alternative form of upper urinary tract diversion is the Sober-en-T ureterostomy, in which the proximal ureter is exteriorized and the distal ureter is kept in continuity with the upper ureter with a proximal ureteroureterostomy.[48] The advantage of this approach is that it permits rapid decompression of the upper urinary tract while permitting urine to pass into the bladder. Fig. 57.5 shows a modification of the original Sober-en-T ureterostomy.

If cutaneous vesicostomy, ureterostomy, or pyelostomy is chosen as initial therapy, valve ablation should not be performed simultaneously because the urethra will remain dry, and urethral stricture formation is common (Fig. 57.6).[49] Another case illustrating the importance of choosing well-planned diversionary procedures and delaying primary valve resection is shown in Fig. 57.7.

CONTROVERSIES IN INITIAL MANAGEMENT OF POSTERIOR URETHRAL VALVES

The initial management of PUV is controversial. In 1997, Close and colleagues suggested that early valve ablation



Figure 57.5 A newborn underwent bilateral cutaneous pyelostomies and transurethral ablation of posterior urethral valves. Before upper tract reconstruction at age 4 years, a catheter could not be passed at the time of the voiding cystourethrogram. The cystogram through a cutaneous ureterostomy shows a complete proximal anterior urethral stricture requiring a perineal approach for reconstruction.

permitted recovery of the normal bladder appearance and function when the procedure was performed within the first month of life. In their patients, urinary diversion was deleterious to ultimate bladder function because of the absence of normal bladder cycling.[46] Patients who underwent diversion had reduced bladder compliance, which resulted in long-term bladder dysfunction. Delayed development of daytime urinary continence occurred in 80% of patients who underwent diversion procedures as opposed to 33% of those who underwent primary valve ablation. However, both groups developed similar degrees of renal dysfunction in the long term.[46]

Podesta and colleagues studied boys with PUV who underwent either vesicostomy and delayed valve ablation or primary valve ablation.[50] These investigators demonstrated that approximately 50% of the diverted group had detrusor overactivity, which was rarely observed in the primary ablation group. The primary ablation group also had a lower detrusor filling pressure at expected bladder capacity for age and improved detrusor compliance.

Although these groups advocated primary valve ablation, their observations on bladder function differed from the 1996 report of Smith and colleagues.[51] These investigators examined the long-term outcome of 100 patients treated with primary valve ablation (74%), vesicostomy (13%), or high diversion (90%). Overall, 13% developed ESRD by age 15 years. Treatment choice did not influence the age at which they developed ESRD. The incidence of chronic renal failure was 34% at age 10 years and 51% at age 20 years. Almost all patients had delayed development of daytime urinary continence; only 19% developed continence by age 5 years and 46% by age 10 years. Although formal urodynamic testing was performed in only 10 patients, only one patient was thought to need an augmentation cystoplasty.[51]

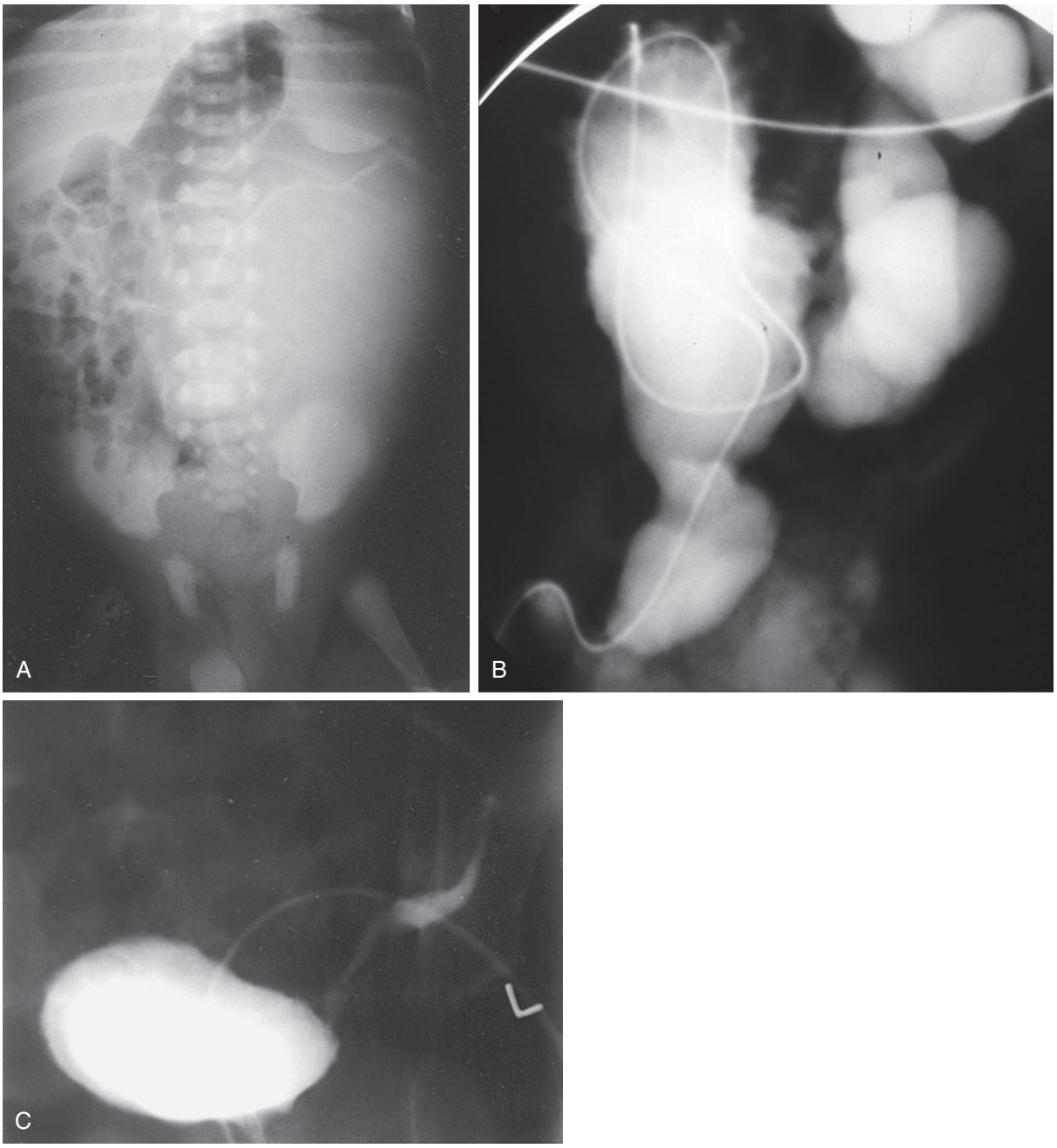


Figure 57.6 A newborn boy was noted prenatally to have left hydronephrosis and a distended bladder. A, Abdominal plain film shows a large left urinoma. B, Voiding cystourethrogram shows high-grade left vesicoureteral reflux and posterior urethral valves. His creatinine concentration was 0.5 mg/dL after 1 week of catheter drainage. During passage of the resectoscope, the glans split, creating a subcoronal hypospadias. Valve ablation proceeded and a left ureterostomy at the midureteral level was performed. Postoperatively, all his urine is noted from the left ureterostomy. Before urinary diversion at age 3 years, a renal scan demonstrates that the left kidney contributes 20% to the total renal function and a cystogram (C) shows reflux into a nondilated left distal ureter, mild trabeculation, and normal capacity for his age (150 mL). Left proximal ureterogram shows no obstruction. Takedown of the left ureterostomy with excision of the left distal ureter and ureteral reimplantation with a psoas hitch are performed. This case demonstrates several points: (1) Ureterostomy is not usually indicated for reflux; (2) ureterostomy should not be performed midureter when reimplantation will be required; (3) once the valve is resected, procedures should not be performed that completely divert urine from the bladder; and (4) care should be exercised when instrumenting the infant male urethra.

Kim and associates[52] compared the urodynamic findings in patients with PUV who underwent primary valve ablation, vesicostomy, or proximal diversion with pyelostomy or ureterostomy. When the urodynamic findings of end-filling detrusor pressure and bladder capacity were compared, no statistical difference was found in any of these groups. In fact, the vesical or proximal diversion groups had somewhat better urodynamic findings. The investigators concluded that the initial management of valve ablation or vesical or proximal diversion does not affect ultimate bladder function. However, adjunctive medical therapy in the treatment groups was difficult to assess.

A report of the long-term follow-up of bilateral high Sober-type urinary diversion in 36 patients with PUV who

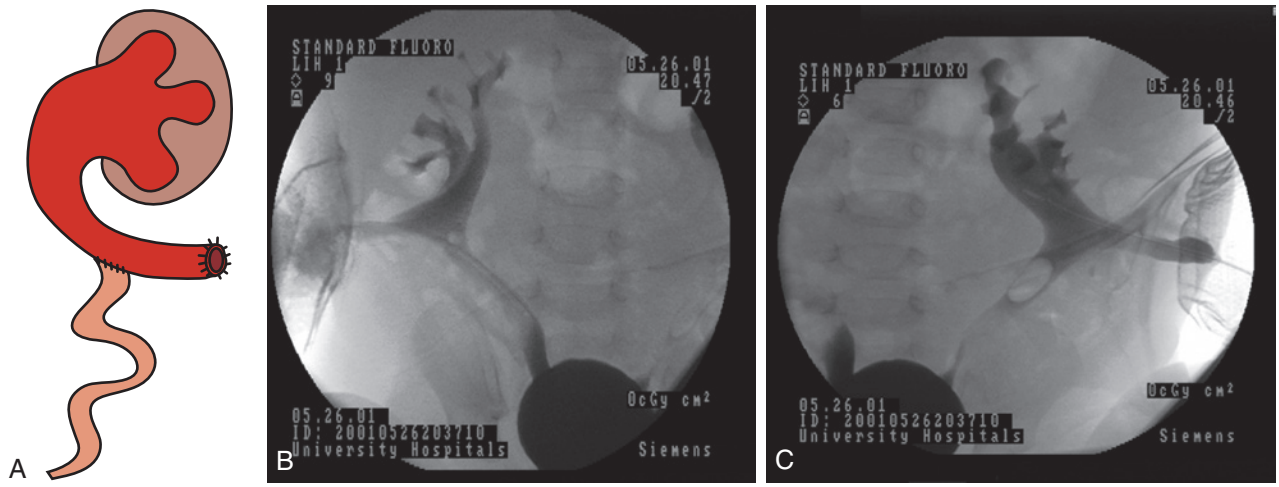


Figure 57.7 A, Sober-en-T ureterostomy decompresses the upper urinary tract and permits urine to pass into the bladder. The proximal ureter is divided below the lower pole of the kidney. The upper end is diverted to the skin. The lower end is anastomosed to the proximal ureter just below the renal pelvis, but not to the pelvis as originally described by Sober. Ureterograms showing the right (B) and left (C) kidneys 1 year after Sober Y-en T ureterostomies. (A, With permission from Liard A, Seguier-Lipszyc E, Mitrofanoff P. Temporary high diversion for posterior urethral valves. *J Urol.* 2000;164[1]:145-8.)

underwent urodynamic testing not only after diversion but also before and after ureterostomy closure showed well-preserved bladder capacity or compliance in 80% and 69%, respectively, and stable detrusor activity in 89%. An increase in bladder capacity was demonstrated in about a third of patients.[48]

Narasimhan and colleagues performed a prospective study of boys with PUV who underwent either primary ablation or vesicostomy.[53] These investigators analyzed the effect of the modality on renal function and somatic growth and whether the presence of VUR and an abnormal serum creatinine concentration affected somatic growth. At birth, body weight and length and serum creatinine concentrations were similar in the two groups, but the valve ablation group lagged behind the vesicostomy group at 3 and 6 months in weight and length measurements. The investigators concluded that treatment modality did not affect the outcome of renal function, because at 1 year the serum creatinine concentration decreased to 0.7 ng/dL in the valve ablation group and to 0.9 ng/dL in the vesicostomy group. Both groups showed delayed growth when compared with normal age-matched controls. Serum creatinine concentration >1.0 mg/dL and the presence of VUR were significantly associated with somatic growth delay by the end of the second year. Vesicostomy appeared to assist with catchup growth in weight and height by the end of the first 2 years of life.

With improved instrumentation, primary valve ablation is recommended as the initial treatment modality of choice when fulguration can be performed safely and when the patient has had improvement in upper tract dilatation with catheter drainage unless the neonate is ill and small. Circumcision is recommended, because it reduces the risk of UTI.[33] Antibiotic prophylaxis should be continued until the massive dilation of the upper urinary tract shows significant improvement, a process that may take several years.[26] In addition, if the child has VUR, prophylaxis should be continued until the reflux resolves spontaneously or is corrected surgically. Most patients benefit not only from long-term urologic management but also from nephrologic care initiated at birth.

Common problems include significant polyuria secondary to an inability of the kidneys to concentrate urine, metabolic acidosis (which may complicate somatic growth), renal insufficiency with hypocalcemia and hyperphosphatemia, and hypertension, as well as vitamin D deficiency and hyperparathyroidism.[54] If the patient remains clinically well with good somatic growth, periodic follow-up with sonography and evaluations of electrolytes, blood urea nitrogen, creatinine, urinalysis, and blood pressure will ensure satisfactory growth and development.

Prognosis Following Initial Therapy

The prognosis for satisfactory renal function may be predicted by several factors. A serum creatinine concentration >1 mg/dL 1 month following initial treatment or at 1 year of age is associated with late development of chronic renal insufficiency.[55] Other investigators concluded that the most significant prognostic factor for the future development of chronic renal failure is the GFR at 1 year of age, and the development of proteinuria portends a worse prognosis.[56] These investigators found no differences in age at diagnosis, initial management, VUR status, UTI, and hypertension in the development of chronic renal insufficiency, whereas sonographic observations may be useful in identifying patients who will develop renal insufficiency. The presence of the corticomedullary junction on renal sonography has been associated with a favorable outcome.[57] This radiologic finding may not be present on the initial ultrasound study but may become apparent during the first few months of life.

In another study, Duel and colleagues showed that 90% of boys with PUV who were followed for a mean of 8.5 years and who ultimately developed poor renal function had echogenic kidneys, whereas 46% of patients with good

renal function also had echogenic kidneys.[58] In addition, 60% of the patients with echogenic kidneys developed poor renal function compared with 13% of the patients with normal renal echogenicity. Increased cortical echogenicity and loss of corticomedullary differentiation were relatively insensitive predictors of eventual renal function in patients with PUV. These investigators found that the serum creatinine concentration following 4 days of catheterization was a more sensitive predictor of outcome in these boys.

Achieving diurnal continence by the age of 5 years also is recognized as a favorable feature.[59] Diurnal incontinence probably is related to detrusor instability and detrusor sphincter discoordination, which can result in elevated upper urinary tract pressures and gradual deterioration in renal function.

A controversial prognostic feature is the presence of a pressure pop-off mechanism, such as massive reflux into a nonfunctioning kidney (termed the *VURD syndrome* for valves, unilateral VUR, dysplasia), urinary ascites, or a large bladder diverticulum.[60,61] Although short-term studies suggested that these mechanisms may allow more normal renal development, Cuckow and colleagues reported that at 8–10 years of age, only 30% of boys with the VURD syndrome had a normal serum creatinine concentration.[62] In another retrospective study, Hoag et al. also found that VURD is not a favorable prognostic feature.[63] The finding that pop-off mechanisms may not always be protective was further supported by Patil and colleagues, who observed that ascites may result from bladder rupture, and GFR in those patients approaches the severe renal failure range.[28]

The detrimental or beneficial effects of VUR on renal function in patients with PUV remain controversial. Some investigators suggest that VUR in combination with high intravesical pressure contributes to deterioration of the upper urinary tract; others propose that VUR, especially when associated with the VURD syndrome, protects the upper urinary tract from high intravesical pressures. Hassan and colleagues reported that VUR in their 73 patients did not serve as a significant prognostic factor for renal function.[64] On the other hand, in a long-term study of 197 adults treated over a period of 50 years, Heikkila et al. found that bilateral VUR is often associated with poorly functioning kideys.[65] Persistent VUR with or without renal deterioration in the absence of UTI may indicate bladder dysfunction and the need for lower urinary tract evaluation.

Another adverse prognostic finding is renal parenchymal area <12 cm^2 on the first postnatal renal ultrasound, especially when the nadir serum Cr is 0.8 to 1.1 mg/dL.[66] Other adverse predictive factors include oligohydramnios, cortical cysts, and echogenic kidneys.[67] Whether antenatal diagnosis is beneficial is controversial.[68]

Vesicostomy Closure

The decision to close a cutaneous vesicostomy must be made carefully. If the patient has had breakthrough febrile UTIs, vesicostomy closure is important because it will reduce the risk of bacterial contamination. In other patients, this procedure may be necessary as a prerequisite to renal transplantation. In most cases, vesicostomy closure is performed after the upper urinary tract has stabilized and the child is large enough to undergo simultaneous valve ablation, generally between 6 months and 3 years.

Preoperatively, a VCUG should be obtained through the vesicostomy to assess the presence of VUR and to evaluate the bladder. In selected cases, urodynamic studies are helpful to assess bladder compliance.[69] Even if VUR is significant and the child is quite young, it is usually safe simply to close the vesicostomy and delay VUR correction until the child is older.

Following closure of the vesicostomy, the upper urinary tract should be monitored carefully to ascertain whether hydronephrosis is worsening and ensure that the child is emptying the bladder satisfactorily. In some cases, anticholinergic medication alone or with clean intermittent catheterization may be needed to improve compliance and bladder emptying. Alpha-blocker therapy may be effective in improving uroflowmetry and bladder emptying in some patients with PUV,[70,71] and Botox injection into the bladder neck is another treatment option.[72] Anticholinergic therapy might be beneficial in improving bladder function and protecting the upper urinary tract from elevated detrusor pressure.[73]

Vesicoureteral Reflux

Vesicoureteral reflux is present in approximately 50% of boys with PUV at presentation, with half bilateral and half unilateral. Following valve ablation, approximately 25% of patients show spontaneous VUR resolution and VUR may resolve as long as 3 years following initial treatment.[64] Antibiotic prophylaxis should be prescribed and assessment with cystography and upper tract imaging should be performed regularly. Hassan and colleagues showed that the rate of VUR resolution was related to the function of the involved kidney, with decreased resolution rates in the more poorly functioning renal units.[64]

Vesicoureteral reflux should be corrected if breakthrough UTIs occur or if it remains high grade. Although most pediatric urologists are adept at performing ureteral reimplantation surgery, reimplanting thick, dilated ureters into the abnormal valve bladder can be most challenging, and a 15–30% complication rate has been reported.[74]

Gearhart and colleagues studied dilated ureters from patients with PUV and demonstrated an increased ratio of collagen to smooth muscle.[75] This quantitative histologic finding was associated with less distensible ureters, which may predispose to failed ureteral reimplantation. In addition, Freedman and colleagues performed quantitative morphometry of 20-week gestational age bladders with PUV and demonstrated a significant increase in both the smooth muscle and collagen components.[76] Both of these observations show that the ureter and bladder can be suboptimal tissues for reconstruction despite the surgeon's best efforts and experience. For these reasons, endoscopic therapy with dextranomer/hyaluronic acid copolymer is an attractive alternative to open surgical intervention in some cases, but no long-term data in patients with PUV are available to support the efficacy of this approach.[77]

In boys with VUR and PUV, often the ureters are dilated and the bladder is thick-walled. Friedman and Hanna described a technique using a distal ureteral split-cuff nipple with a long

ureteral trough within the detrusor, often associated with a psoas hitch.[78] Results were quite favorable, and hydronephrosis was improved in 2/3 of the 45 megaureters.

In boys with the VURD syndrome, nephrectomy should be performed at some point.[50] The ureter should be removed, unless the bladder is small or poorly compliant, in which case ureterocystoplasty should be considered.[79] Following this procedure, the solitary kidney should be followed carefully for the development of hydronephrosis, because the pressure pop-off mechanism has been removed.[80] Narasimhan and colleagues demonstrated that when the contralateral kidney demonstrates evidence of renal scarring, renal function is more likely to be impaired.[81]

Bladder Dysfunction

Children with PUV have a spectrum of urodynamic findings. Favorable prognostic signs include pop-off mechanisms such as bladder diverticulum, patent urachus, and urinoma.[60,61] These pop-off mechanisms protect the bladder and assist in predicting bladder function. Kaefer and associates found that 71% of their patients had at least one pop-off mechanism, and 87% of these patients had favorable urodynamic findings such as satisfactory compliance and bladder capacity.[61] Only 55% of patients without a pop-off mechanism had favorable urodynamic findings. In the group who had no pop-off mechanism and unfavorable urodynamic findings, five of seven patients underwent augmentation cystoplasty.

Urinary incontinence in patients who have a history of PUV has several causes, including myogenic failure and overflow, uninhibited detrusor contractions, severe polyuria, high-pressure voiding secondary to incomplete valve resection with resultant outlet obstruction, stress urinary incontinence, and valve bladder syndrome (Fig. 57.8).[82,83] The term *valve bladder syndrome* refers to the bladder with poor detrusor compliance resulting from fibrosis secondary

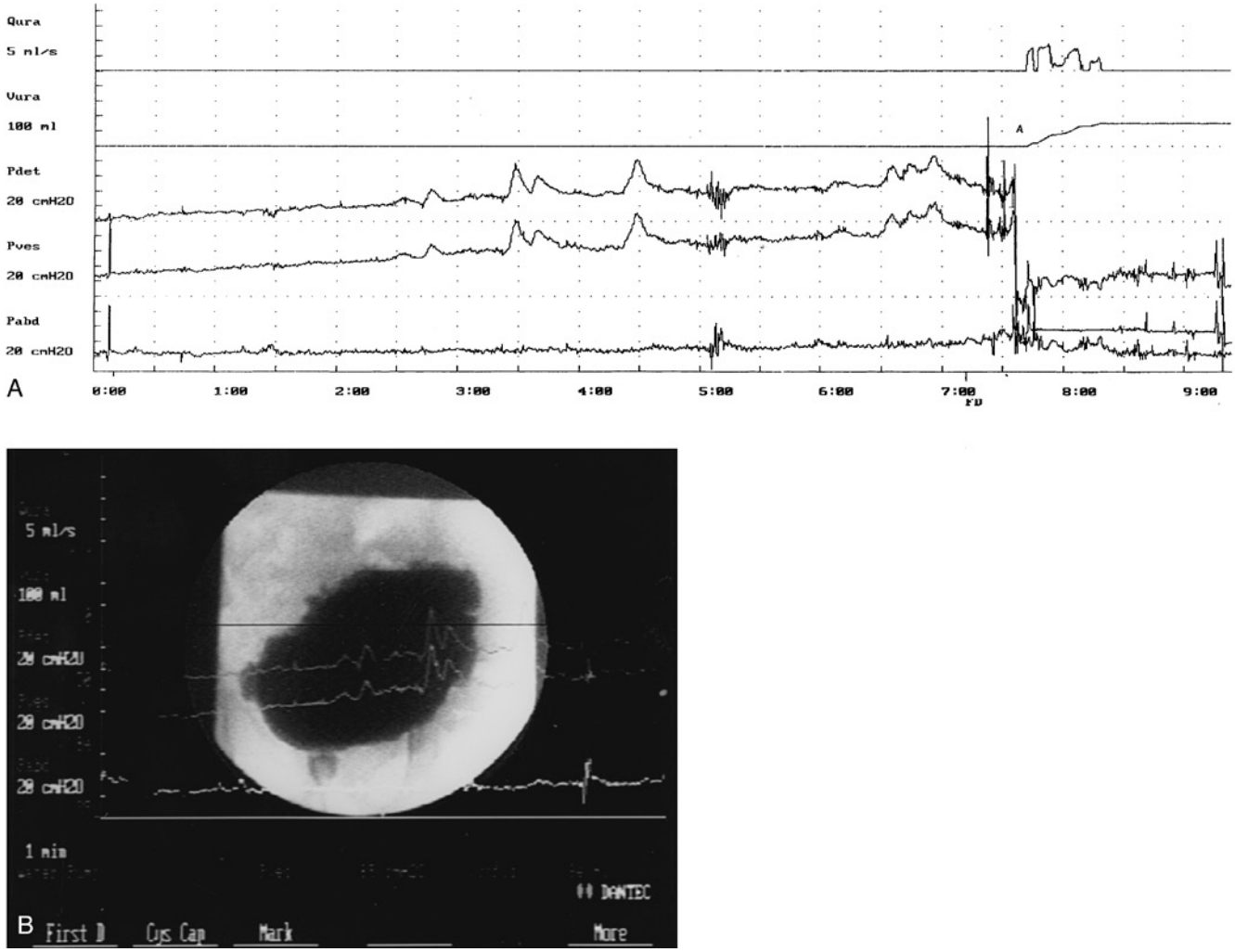


Figure 57.8 Urodynamic study of a 5-year-old boy with a history of posterior urethral valves resected at the age of 4 years. He has day and night incontinence and bilateral hydronephrosis evident on an ultrasound scan. A, Urodynamic tracing shows progressive loss of compliance with detrusor instability and no urinary flow with the urethral catheter in place. When the catheter is removed at A, the flow is weak and intermittent. B, The video portion of the study shows a trabeculated bladder with multiple diverticula and residual valve. Pabd, abdominal pressure; Pdet, detrusor pressure; Pves, total bladder pressure; Qura, uroflow rate; Vura, voided volume. (With permission from Horowitz M, Combs AJ, Shapiro E. Urodynamics in pediatric urology. In: Nitti VW, ed. Practical Urodynamics. Philadelphia: WB Saunders; 1998:262.)

to long-standing obstruction. This condition may cause secondary ureteral obstruction with worsening hydronephrosis if bladder pressure is >35 cm H_2O. The full valve bladder syndrome often is complicated by polyuria, which results from an inability of the chronically obstructed kidneys to concentrate urine. Polyuria results from nephrogenic diabetes insipidus caused by impaired medullary development with a paucity of collecting duct formation. This problem is common and may make it necessary for the child to void frequently to avoid upper urinary tract changes. Therefore, continence is difficult to achieve.

Initial therapy probably should consist of double or triple voiding. In addition, these patients usually require anticholinergic therapy and clean intermittent catheterization with or without augmentation cystoplasty.[83] Options include the usual segments of bowel, although these patients may then require bicarbonate supplementation unless stomach or ureter associated with a nonfunctioning kidney is used for augmentation.[79,84]

Koff and associates[85] evaluated the pathophysiology of the valve bladder syndrome. These investigators proposed that the cause of the valve bladder was chronic overdistention of the bladder during sleep as a result of polyuria, impaired bladder sensation, and residual urine. Because daytime decompression alone was insufficient, the investigators proposed nocturnal bladder emptying by placement of an indwelling catheter, intermittent nocturnal catheterization, or frequent nocturnal double voiding. Chronic hydronephrosis improved significantly or resolved completely in all patients. Serum creatinine concentrations improved in six of 18 patients, four of whom deteriorated and two of four of whom underwent renal transplantation.[85] In boys who resist overnight catheterization through the penis, a Mitrofanoff appendicovesicostomy may be performed.

Several distinguishable urodynamic patterns have been recognized in patients with PUV and vary depending on age (Fig. 57.9). Holmdahl and colleagues showed that the urodynamic pattern in infancy is characterized by hypercontractility and low bladder capacity.[86] During the first 3 years of life, the pattern changes with resolution of the hypercontractility to instability with emptying difficulties. Bladder emptying resulting from some degree of myogenic failure is again seen as a late, postpubertal problem.

Holmdahl and colleagues also studied bladder dysfunction before and after puberty.[87] In prepubertal patients, urodynamic features at presentation were again noted to be uniform with hypercontractility and diminished bladder capacities. The voiding pattern in early childhood was one of small, frequent voids during the day and no voids during sleep. Hypercontractility improved with age. After puberty, the bladders were found to be highly compliant, whereas instability and emptying difficulties remained unchanged. The bladder increased to a normal capacity in prepubertal boys, but mean bladder capacity was twice the normal size in postpubertal patients. Fifty percent of these dilated, decompensated bladders could not develop a sustained detrusor contraction. In these patients, a Valsalva maneuver was required to empty the bladder. The development of myogenic failure may be associated with polyuria. Because the urodynamic pattern changes during infancy, in early childhood, and before and after puberty, these patients should be followed carefully with periodic

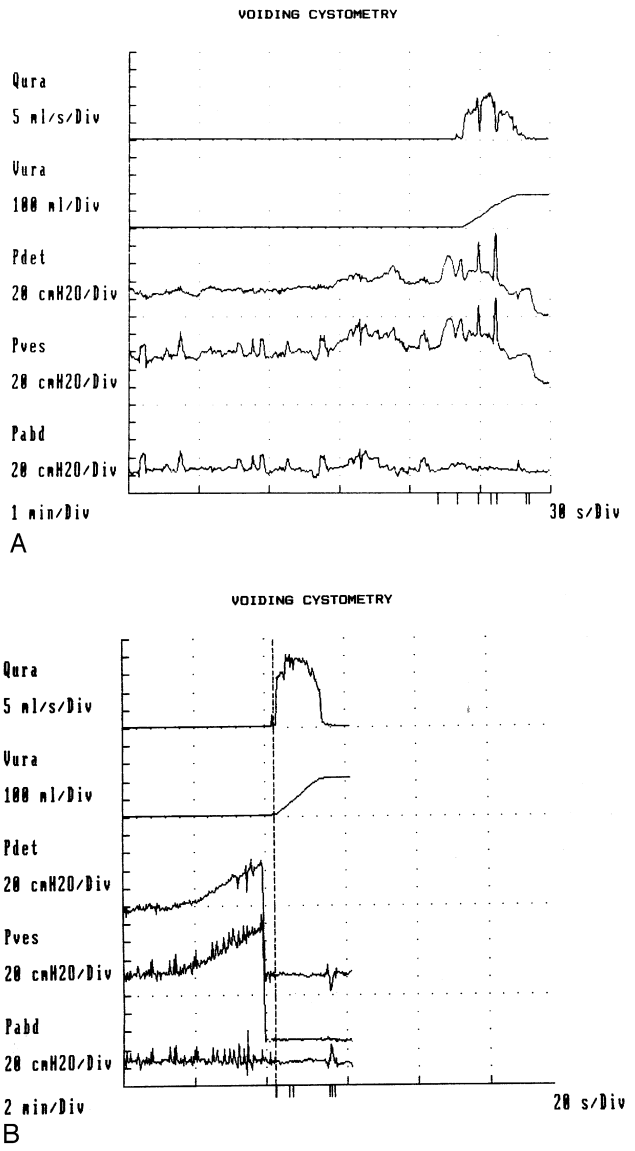


Figure 57.9 Urodynamic study of an 8-year-old boy with a history of posterior urethral valves who had a previous valve ablation. The child has persistent incontinence day and night. A, Tracing from the terminal portion of the urodynamic study demonstrating instability and impaired compliance (Pdet = 40 cm H_2O) before voiding. During voiding, with a 7Fr urethral catheter in place, a choppy flow pattern is noted with Qmax = 14.2 mL/second with 192 mL voided and no post-void residual. A significant component of the voiding pressure came from elevated pressure secondary to impaired compliance. B, Repeat study, with a faster fill, demonstrating a similar degree of impaired compliance (Pdet = 40 to 45 cm H_2O at capacity). The catheter was removed, and the patient voided with a Qmax of 20.7 mL/second with a normal-shaped flow curve. This study demonstrates the existence of bladder dysfunction; however, it is not secondary to persistent obstruction. Pabd, abdominal pressure; Pdet, detrusor pressure; Pves, total bladder pressure; Qura, uroflow rate; Vura, voided volume. (With permission from Horowitz M, Combs AJ, Shapiro E. Urodynamics in pediatric urology. In: Nitti VW, ed. Practical Urodynamics. Philadelphia: WB Saunders; 1998:263.)

videourodynamics to identify changes that may ultimately affect upper urinary tract function and drainage.[88]

Delayed Presentation of Posterior Urethral Valves

Bomalaski and colleagues described 47 patients, ages 5 to 35 years (mean 8 years), who were investigated for diurnal enuresis (60%), UTI (40%), and voiding pain (13%) and were found to have PUV.[89] Hydronephrosis was observed in 40% and VUR in 33%. Only 10% presented with a poor urinary stream, gross hematuria, and proteinuria. The serum Cr before valve ablation was elevated in 35%, whereas 10% had ESRD at presentation. These investigators noted that if the VCUG had been performed only in patients with an abnormal renal ultrasound scan or UTI, 30% of PUV would not have been diagnosed. Only one of those patients had an elevated serum creatinine, a finding supporting the notion that severity of signs and symptoms is significantly associated with renal impairment. The investigators recommended performing VCUG in boys >5 years old who have voiding complaints, especially associated with diurnal enuresis or UTI.

Schober and colleagues studied 70 boys (mean age 7.5 years; range 2–14 years) with delayed presentation of PUV who were undergoing valve ablation.[90] Dysfunctional voiding was the most common symptom, with nocturnal enuresis in 67% and urinary frequency in 60%. UTI occurred in 17%. Microhematuria was found in 30%, and mild age-corrected hypertension was noted in 17%. Serum creatinine concentrations were normal in all patients. Despite adequate valve resection, 63% of these patients had persistent dysfunctional voiding.

Ziylan and colleagues reported on 36 patients with PUV who were diagnosed at a mean age of 8.8 years (range 5–14 years).[91] The investigators compared the posttreatment urodynamic findings and renal function in the delayed presentation group (n = 20 with a mean age of 10.65 years at urodynamic evaluation) with age-matched controls who were children with PUV diagnosed and treated at <5 years of age (n = 19, mean age of 8.52 years). Abnormal urodynamic findings included detrusor overactivity in three (15%), significant postvoid residual in nine (45%), and an enlarged bladder capacity in nine (45%) patients. No significant difference was noted in bladder capacity, compliance, or post-void residual in the late presentation versus control group, whereas detrusor overactivity was significantly lower in the late presentation group. After approximately 5 years of follow-up, age-specific Cr levels were increased in 13 of 27 patients with late presentation, and seven (25.9%) of these patients developed ESRD. Renal function was significantly impaired in the late presenters compared with controls (48.1% versus 13.7%), with mean serum Cr levels of 2.17 and 1.03 mg/dL, respectively. Although renal function was significantly impaired in the patients with late presentation, the investigators reported a similar pattern of bladder dysfunctions in this older age group with PUV. In a recent meta-analysis, Hennus et al. reported that urodynamic abnormalities were found in 55% of children with PUV.[92]

Progression to End-stage Renal Disease and Renal Transplantation

Proteinuria results when the kidney has decreased functional reserve and in infancy is related to a worse prognosis.[56] To keep up with the child's growth, the functioning nephrons undergo hyperfiltration to attempt to maintain normal renal function. Excessive filtration leads to proteinuria and focal segmental glomerulosclerosis and renal failure. In a study of boys with PUV, proteinuria was present in 79% of patients with chronic renal failure compared with only 17% with normal renal function. One study suggested that angiotensin blockade may effectively control proteinuria and stabilize renal function in children with nondiabetic proteinuric kidney disease.[93]

Chronic renal failure affects puberty by influencing hypothalamic control of the onset and progression of pubertal growth and gonadarche, but puberty also affects chronic renal failure.[93] Pubertal acceleration of kidney dysfunction has been observed in VUR and PUV, whereas sex steroids alter kidney growth and function. Androgens are known to stimulate the renin-angiotensin II system by producing higher blood pressures in male patients. Androgens also promote normal and abnormal kidney growth and have been shown in animals to promote kidney damage.[94]

Holmdahl and Sillén[94] reported on long-term outcomes in patients with PUV who were 31–44 years old; these investigators focused on renal function, bladder function, and paternity. Of 19 male patients available for follow-up, 32% were uremic, 21% had moderate renal failure, and 47% had had no follow-up since adolescence. All patients were continent, although bladder dysfunction was reported in 40%, all of whom described detrusor weakness including weak urine stream, the need for double voiding, and urinary residual. Only five of 19 patients had experienced daytime continence at age 5 years. Infertility was associated with uremia. This study highlights the importance of long-term follow-up because of the risk of late renal impairment in 25–50%.[51] These investigators further noted that 50% of their patients who initially had favorable renal function and a low incidence of reflux had no clinical problems related to renal function.[95]

Tikkinen et al. studied the voiding habits of 68 adult men (median age 38.5 years) with a history of PUV and found that 32.4% had a bothersome lower urinary tract symptom, compared with 15.8% of controls.[96] In a larger cohort of patients from the same series, 23% had ESRD.[97]

Of all male patients with ESRD, 0.2% have a primary diagnosis of congenital obstructive uropathy.[98] Although transplantation before 5 years of age is thought to result in better somatic growth and neurologic development, bladder compliance and stability at >5 years of age is usually more favorable for transplantation.[44] Specific attention has focused on treating bladder dysfunction, because it influences the success of renal transplantation. Graft survival rates, patient survival rates, and serum Cr in boys with a history of PUV are now similar to those of patients without bladder outlet obstruction who require renal transplantation.[99] For example, DeFoor and colleagues reported their

experience between 1990 and 2000 with 10 patients with PUV, mean age 10 years, who underwent 13 renal transplants.[100] Although the mean follow-up in this report was only 3.9 years, cumulative allograft survival was 85% and 64% at 1 and 5 years, respectively. Nine of 10 patients had functioning living related donor transplants, and one patient lost three cadaveric transplants through chronic rejection. The mean serum creatinine concentration of patients with functioning grafts was 1.1 mg/dL. No grafts were lost to infection or bladder dysfunction. This study underscores the need for meticulous management of lower urinary tract dysfunction because prompt recognition and treatment of lower tract dysfunction result in successful graft function comparable to that of the general transplant population and obviate the need for augmentation cystoplasty in many cases.

Careful urodynamic evaluation and management of lower tract dysfunction with anticholinergic medication with or without intermittent catheterization ensure success in this selected group of patients. Most of these patients do not require bladder augmentation. If augmentation is required, it can be performed before renal transplantation and the start of long-term immunosuppression. However, some argue that augmentation should be delayed, since many valve bladders develop myogenic failure.[101] In addition, augmentation enterocystoplasty has been demonstrated to increase the risk of UTI following renal transplantation.[101,102] If bladder augmentation is needed after the transplant, one should proceed when the immunosuppressive regimen has been tapered.

Conclusions

The diagnosis and management of PUV continue to evolve with improved ultrasound technology and new techniques for fetal intervention. Advances in endoscopic instrumentation permit early surgical intervention for most neonates. Following initial treatment, recognition and prompt treatment of bladder dysfunction, including the valve bladder syndrome, optimizes the likelihood of preserving long-term renal function and furthers our knowledge of the underlying pathophysiology of bladder outlet obstruction. Bladder function in boys with PUV often changes over time. In patients with PUV and ESRD, renal transplantation is very effective.

References

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Chapter 57 Questions

1. A male newborn is admitted with an antenatal diagnosis of bilateral hydroureteronephrosis, a distended bladder, and reduced amniotic fluid volume. The urologist should:
   a. Order a nephrology consult
   b. Insert a Foley catheter into the bladder
   c. Obtain a renal/bladder ultrasound
   d. Obtain a voiding cystourethrogram
   e. Insert a pediatric feeding tube into the bladder

2. A pregnant mother is diagnosed at 20 weeks' gestation with a male fetus with bilateral hydronephrosis, a distended bladder, and normal amniotic fluid volume. The next step is:
   a. Repeat fetal ultrasound in 4 weeks
   b. Perform a fetal karyotype
   c. Perform an amniocentesis
   d. Perform fetal vesicocentesis
   e. Refer for genetic counseling

3. A pregnant mother is diagnosed at 28 weeks' gestation with a male fetus with bilateral hydronephrosis, a distended bladder, and oligohydramnios. Fetal karyotype is 46,XY. Fetal vesicocentesis shows sodium 105 mEq/L, chloride 96 mEq/L, osmolality 216 mOsm/L, and β_2-microglobulin 3.6 mg/L. The next step is:
   a. Counsel patient for vesicoamniotic shunt
   b. Counsel patient that the baby probably will have renal failure
   c. Recommend fetal cystoscopic valve resection
   d. Perform repeat vesicocentesis in 2–3 days
   e. Observe with repeat ultrasound until delivery

4. A male newborn born at 34 weeks' gestation has suspected PUV. He is on a ventilator and has a right pneumothorax. A renal ultrasound demonstrates echogenic kidneys, severe bilateral hydroureteronephrosis, and a distended bladder. What conclusion can be drawn?
   a. This baby will have ESRD despite treatment
   b. Prognosis is uncertain based on this information
   c. Renal biopsy should be performed to determine treatment plan
   d. Upper urinary diversion will provide the best outcome
   e. Vesicostomy is recommended because the baby is too small for valve resection

5. A male term newborn with bilateral hydronephrosis is diagnosed with posterior urethral valves based on antenatal ultrasound, postnatal ultrasound, and voiding cystourethrogram. The appropriate treatment is:
   a. Placement of suprapubic tube by interventional radiology and schedule valve ablation when baby is stable
   b. Place on antibiotic prophylaxis and schedule for valve ablation after 52 weeks' gestation
   c. Perform cystoscopy, transurethral valve ablation, circumcision, and prescribe antibiotic prophylaxis
   d. Obtain follow-up renal/bladder ultrasound in 2 weeks
   e. Perform newborn circumcision to reduce the risk of urinary tract infection

6. A newborn male with posterior urethral valves demonstrates grade V vesicoureteral reflux into the left kidney. A renal scan demonstrates nonfunction of the left kidney. What conclusion can be drawn?
   a. Left ureterostomy might preserve left renal function
   b. Left renal biopsy will predict whether the left kidney has potential function
   c. VURD syndrome (valves, unilateral reflux, dysplasia) is a protective factor for the upper urinary tract, and the patient's renal function should be normal
   d. When left nephrectomy is performed, left ureterocystoplasty should be considered
   e. Monitoring for proteinuria will determine prognosis

7. A term male newborn with posterior urethral valves is undergoing transurethral valve ablation. It is difficult to pass the pediatric cystoscope. What conclusion can be drawn?
   a. A circumcision should be performed to make it easier to pass the cystoscope
   b. The urethral meatus should be dilated gently with metal sounds
   c. A perineal urethrostomy should be performed to allow the cystoscope to be inserted
   d. A temporary vesicostomy should be performed
   e. The procedure should be delayed until the patient is older and the urethra is larger

8. A male newborn with posterior urethral valves has severe bilateral hydroureteronephrosis and a rising serum creatinine despite catheter drainage of the bladder. Bilateral cutaneous pyelostomies are being considered to maximize upper urinary tract drainage. This procedure would:
   a. Prevent ESRD if performed promptly
   b. Allow antegrade assessment of the ureters to determine whether there is ureterovesical junction obstruction
   c. Avoid the need for antimicrobial prophylaxis
   d. Increase the likelihood of a noncompliant bladder
   e. Facilitate total urinary tract reconstruction

9. In delayed presentation of PUV, common symptoms and clinical studies include all of the following except:
   a. Abdominal pain
   b. Diurnal incontinence
   c. Urinary tract infection (UTI)
   d. Hydronephrosis
   e. Elevated serum Cr

10. A 15-year-old boy with treated PUV has ESRD and is being evaluated for living-related renal transplantation. What conclusion can be drawn?
    a. Augmentation enterocystoplasty should be performed before transplantation if the bladder capacity is less than 250 mL

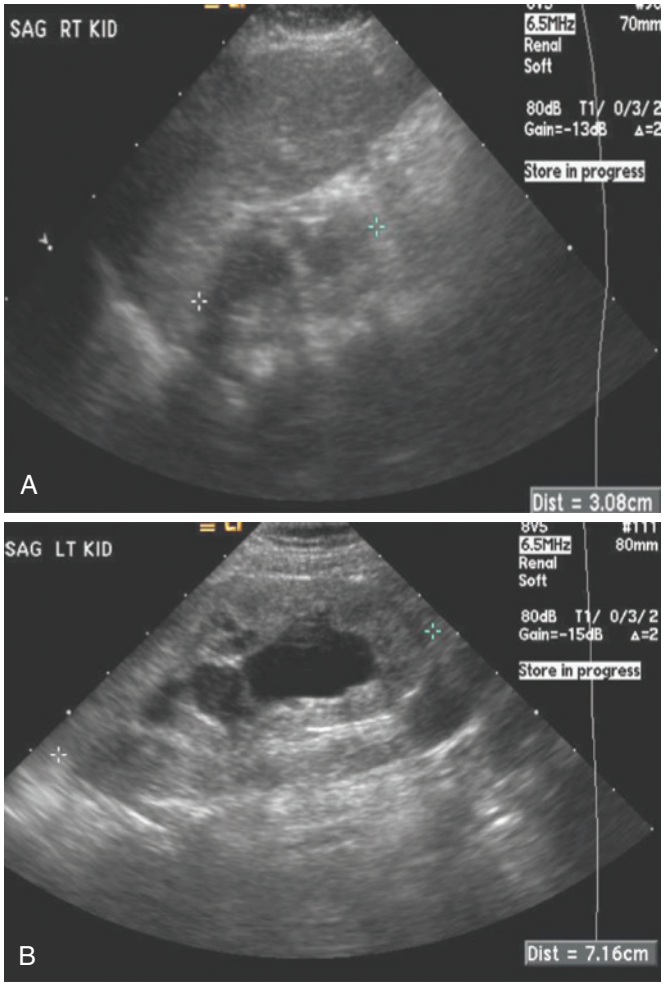
b. He has an increased risk of UTI following transplantation
c. The 5- and 10-year graft survival is similar to that of patients without PUV
d. Performing an antirefluxing ureteral anastomosis has been shown to increase the likelihood of graft survival
e. Nephrectomy and ureterocystoplasty should be performed before transplantation

Case Studies

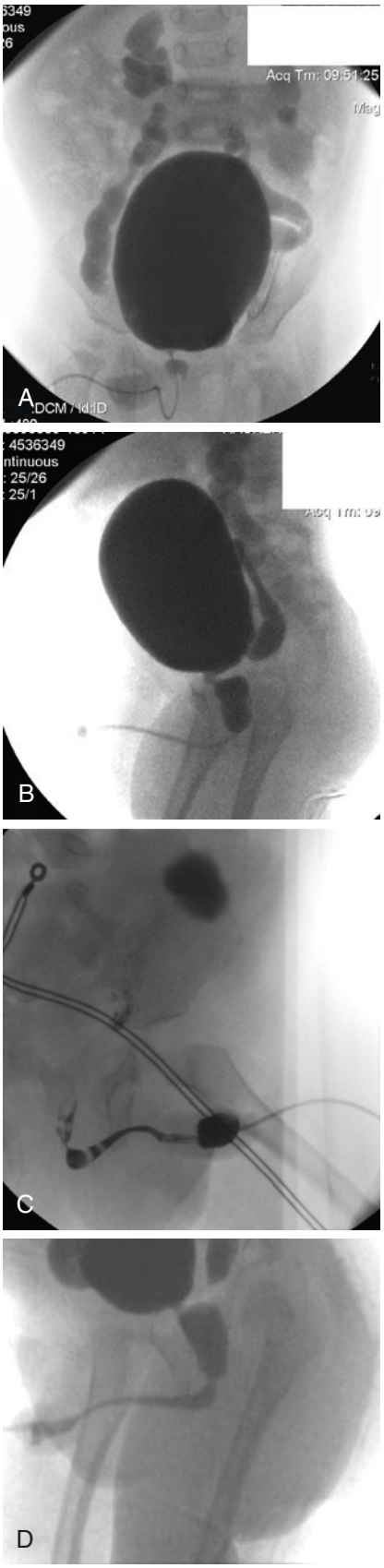
CASE 1

A 9-month-old boy has a history of prenatally diagnosed bilateral hydroureteronephrosis and oligohydramnios. Postnatally, he was found to have a small dysplastic right kidney, a left hydronephrotic kidney, bilateral grade V vesicoureteral reflux, and PUV. Transurethral incision of the valve leaflets was performed at 1 week of age. The serum creatinine decreased to 0.7 mg/dL. He subsequently had four episodes of pyelonephritis. The patient is uncircumcised.

Case Fig. 57.1 demonstrates the renal US. Case Fig. 57.2 demonstrates the voiding cystourethrogram.



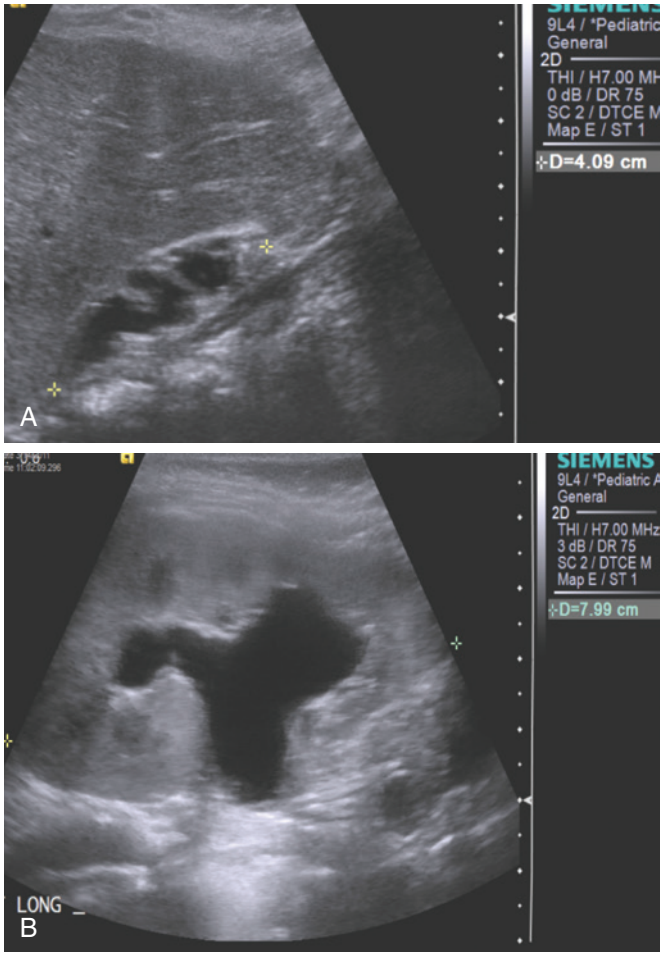
Case Figure 57.1



Case Figure 57.2

1. The radiologic studies demonstrate:
   a. Right reflux nephropathy, bilateral vesicoureteral reflux
   b. Right reflux nephropathy, bilateral vesicoureteral reflux, and a distal megalourethra
   c. Persistent PUV, bilateral vesicoureteral reflux, right reflux nephropathy, and a distal megalourethra
   d. Bilateral vesicoureteral reflux with bilateral ureterovesical junction obstruction
   e. Bilateral vesicoureteral reflux, right reflux nephropathy, left ureteropelvic junction obstruction, and distal megalourethra

2. The appropriate treatment is:
   a. Transurethral ablation of residual valve leaflets, bilateral subureteral injection of detranomer/hyaluronic acid, circumcision, antibiotic prophylaxis
   b. Transurethral ablation of residual valve leaflets, repair of distal megalourethra, circumcision, antibiotic prophylaxis
   c. Transurethral ablation of residual valve leaflets, repair of distal megalourethra, circumcision, bilateral ureteral reimplantation
   d. Transurethral ablation of residual valve leaflets, circumcision, left pyeloplasty, antibiotic prophylaxis
   e. Circumcision, antibiotic prophylaxis



Case Figure 57.3

At 6 years of age, the patient is not yet toilet trained. He is incontinent both day and night. His urine output is approximately 75 mL/hour. He has not had a UTI. VCUG shows persistent vesicoureteral reflux. Serum creatinine is 0.9 mg%. The renal US is in Case Fig. 57.3.

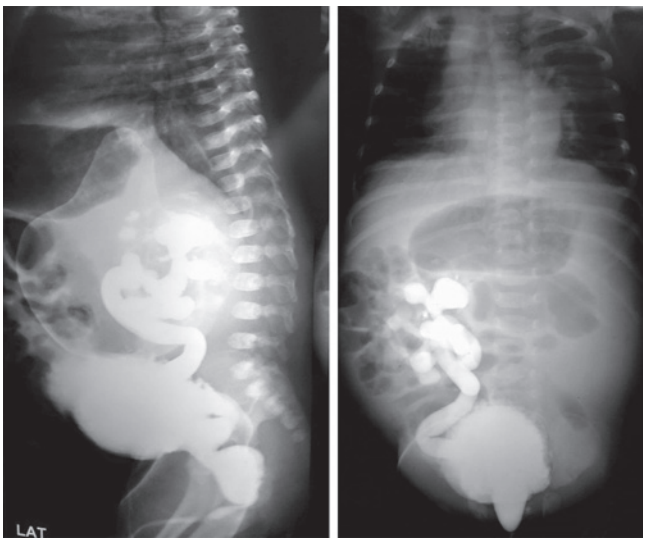
3. Which treatment option would *not* be appropriate?
   a. Daily alpha-blocker
   b. Timed voiding during the day
   c. Leaving a catheter in the bladder overnight
   d. Right nephrectomy, ureterocystoplasty, and left ureteral reimplantation
   e. Inject Botox into the bladder neck

CASE 2

A 6-month-old circumcised boy develops a febrile urinary tract infection. The renal/bladder US shows bilateral hydroureteronephrosis with thin right renal parenchyma, a small amount of fluid adjacent to the right kidney, and a distended trabeculated bladder. The VCUG is demonstrated in Case Fig. 57.4. Following bladder decompression, the serum Cr decreases from 1.5 mg% to 1.2 mg%. A renal scan demonstrates minimal function in the right kidney.

1. What is the appropriate treatment?
   a. Transurethral valve ablation, insertion of a drain adjacent to the right kidney, and antibiotic prophylaxis
   b. Transurethral valve ablation and antibiotic prophylaxis
   c. Cutaneous vesicostomy and antibiotic prophylaxis
   d. Transurethral valve ablation, right cutaneous ureterostomy, and antibiotic prophylaxis
   e. Bilateral cutaneous ureterostomies

Following transurethral valve ablation, at 4 1/2 years of age, the patient has diurnal and nocturnal incontinence. He recently developed a febrile UTI despite antibiotic prophylaxis. He is taking oxybutynin 4 mg TID. A renal ultrasound demonstrates moderate bilateral hydronephrosis



Case Figure 57.4

with thin parenchyma on the right side. Videourodynamics demonstrates a bladder capacity of 75 mL with an uninhibited bladder contraction at 50 mL. Serum Cr is 1.2 mg%.

2. What is the appropriate treatment?
   a. Right ureteral reimplantation
   b. Right-to-left transureteroureterostomy
   c. Change antibiotic prophylaxis
   d. Right nephrectomy and ureterocystoplasty
   e. Botox injection of bladder

The patient is now 12 years old and has a solitary left kidney with mild hydroureteronephrosis. The serum creatinine is 2.7 mg%. He has not had a UTI since age 5 years. Videourodynamics demonstrates a bladder capacity of 250 mL with mild trabeculation and bladder instability at 220 mL. He is being evaluated for living-related renal transplantation.

3. What conclusion can be drawn?
   a. He will need augmentation cystoplasty before renal transplantation
   b. His transplant is likely to fail early because of the history of posterior urethral valves
   c. An antireflux transplant ureteral anastomosis is likely to become obstructed
   d. He will have a significant risk of UTIs following transplantation and will require lifelong antibiotic prophylaxis
   e. The bladder instability probably will resolve in adolescence

Answers

1. **e.** In this case, the most likely diagnosis is posterior urethral valves (PUV), although prune belly syndrome and high-grade bilateral vesicoureteral reflux are other possibilities. A feeding tube should be inserted into the bladder for lower urinary tract decompression and to provide maximum decompression of the upper urinary tract. A Foley catheter is more difficult to pass, and the balloon can cause significant bladder spasm and even obstruct the ureters.
2. **a.** PUV is a likely diagnosis, but intervention such as an amniocentesis or vesicocentesis is unncessary at this time. The male fetus with oligohydramnios at this time is at greatest risk for neonatal complications such as pulmonary hypoplasia.
3. **d.** This fetus is at significant risk for pulmonary hypoplasia without treatment. The fetal urinary sodium, chloride, and osmolality are consistent with high-risk end-stage renal disease (ESRD), but the β_2-microglobulin is more favorable. Studies have demonstrated that serial vesicocentesis can provide a more accurate assessment of potential fetal renal function. Consequently, repeat vesicocentesis in 2–3 days should be performed, and if there are favorable indices, then fetal intervention should be considered.
4. **b.** Cortical cysts and prolonged oligohydramnios are adverse prognostic features in boys with PUV. However, echogenic kidneys at birth ultimately may have relatively normal renal function, and most babies with PUV have severe bilateral hydroureteronephrosis and a distended bladder. A pediatric feeding tube should be inserted and a follow-up renal ultrasound and VCUG should be performed to confirm the diagnosis of PUV.
5. **c.** The most appropriate initial therapy for the vast majority of boys with PUV is cystoscopy with transurethral valve ablation, assuming that the child can undergo anesthesia safely. It can even be performed in the NICU under sedation and caudal anesthesia. Circumcision has been demonstrated to reduce the risk of UTI in boys with PUV, and antibiotic prophylaxis with amoxicillin is beneficial in reducing the risk of UTI, even in the absence of VUR. Rarely is there a need for placement of a temporary suprapubic tube.
6. **d.** This child has the VURD syndrome. Usually the affected kidney is removed, and the ureter should be preserved for possible ureterocystoplasty to augment the bladder, rather than discarding the entire ureter. The kidney does not function, and ureterostomy will not improve function. Although early studies suggested that VURD syndrome was predictive of good long-term renal function, more recent studies with longer follow-up have demonstrated that many children ultimately have reduced renal function.
7. **b.** When the urethral meatus is too small for the cystoscope, forcing the cystoscope can result in a distal urethral (navicular) stricture. Gently passing increasing sizes of lubricated metal sounds should allow the cystoscope to pass without injuring the urethra. Although a circumcision is recommended, it will not make it easier to pass the cystoscope. A temporary vesicostomy is appropriate if the baby is very small.
8. **d.** One of the long-term risks of bilateral cutaneous ureterostomies is diverting all of the urine away from the bladder, which often results in a small, noncompliant bladder. For that reason, the Sober-en-T ureterostomy was developed, which allows urine to drain out through the flank as well as down the ureter into the bladder.
9. **a.** In boys over 5 years old diagnosed with PUV, the most common clinical presentation is dysfunctional voiding with diurnal incontinence urinary frequency, and nocturnal enuresis. Hydronephrosis, an elevated serum Cr, microhematuria, and hypertension also are common.
10. **c.** Renal transplantation is quite successful in patients with a history of PUV and has a graft success rate similar to patients without a history of PUV. Augmentation enterocystoplasty usually is delayed until after the transplant, but patients who undergo augmentation enterocystoplasty have a higher risk of UTI. Nephrectomy generally is unnecessary in patients with PUV.

CASE 1

1. **c.** The VCUG demonstrates persistent PUV with bilateral vesicoureteral reflux. Also, the distal urethra has a megalourethra (possible urethral diverticulum)

pattern. The renal ultrasound shows a 3.1-cm echogenic right kidney and a 7.2-cm left kidney with mild hydronephrosis. The small right kidney is indicative of reflux nephropathy with renal dysplasia.

2. **b.** This baby has evidence of persistent obstructive uropathy with a poorly functioning right kidney and a mildly hydronephrotic left kidney with significant residual bladder outlet obstruction. He needs to undergo transurethral ablation of residual valve to facilitate normal micturition. In addition, because of the UTI, he would benefit from circumcision and should receive antibiotic prophylaxis because of the bilateral vesicoureteral reflux. Repair of the distal megalourethra is an option.
3. **d.** The patient has evidence of a "valve bladder," with polyuria and persistent diurnal incontinence. All of the described treatment options might improve the patient's clinical condition. However, he is at significant risk for progressive renal deterioration. With the persistent severe right vesicoureteral reflux into a poorly functioning kidney and persistent left vesicoureteral reflux, following urodynamics, the most appropriate option would be to perform a right nephrectomy, ureterocystoplasty, and left ureteral reimplantation.

CASE 2

1. **b.** The VCUG shows classic posterior urethral valves with a trabeculated bladder and grade V right vesicoureteral reflux with intrarenal reflux and possibly perirenal urinary extravasation. The patient needs to undergo transurethral valve ablation. It is unlikely that cutaneous ureterostomies or a cutaneous vesicostomy will be beneficial. However, antibiotic prophylaxis should be prescribed because of the high-grade right vesicoureteral reflux.
2. **d.** The patient's UTI most probably is related to his right vesicoureteral reflux into a poorly functioning kidney. His bladder capacity is small, and he would benefit from augmentation cystoplasty, which can be performed utilizing the right ureter in conjunction with right nephrectomy. He might need to perform clean intermittent catheterization following this reconstructive procedure.
3. **e.** Long-term results of valve bladders suggest that they typically have bladder instability until puberty, at which time they become atonic. Consequently, it would be appropriate to proceed with renal transplantation.

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58 Complications of Ureteral Reimplantation, Antireflux Surgery, and Megaureter Repair

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CHAPTER OUTLINE

Nonsurgical Complications
Risks of Medical Management
Bladder Dynamics and Vesicoureteral Reflux
Surgical Complications of Ureteral Reimplantation in the Nondilated Ureter
Technical Considerations
Postoperative Evaluation and Identification of Complications
Early Complications
Low Urine Output
Infections and Voiding Dysfunction
Late Complications
Ureteral Obstruction
Postoperative Reflux
Ipsilateral Reflux
Contralateral Reflux
Managing the Failed Reimplant
Complications of Endoscopic Correction of Vesicoureteral Reflux
Surgical Complications of Laparoscopic/Robotic Reimplant
Surgical Complications of Megaureter Repair
Surgical Complications of Ureterocele Repair
Conclusions
Chapter 58 Questions and Answers

KEY POINTS

1. Open surgical correction of vesicoureteral reflux (VUR) remains the gold standard, with success rates >98% in most pediatric centers.
2. The primary goal of the treatment of VUR is to prevent pyelonephritis that may lead to reflux nephropathy with subsequent hypertension, poor somatic growth, renal insufficiency, and end-stage renal disease.
3. Despite aggressive medical and surgical management, reflux nephropathy accounts for 3% to 25% of cases of end-stage renal disease in children and 10% to 15% of cases of renal failure in adults.
4. Undiagnosed or underestimated bladder disease is a common cause of failed ureteral reimplants.
5. Important technical considerations for ureteral reimplantation include the following:
   - Adequate detrusor backing for the ureter in its submucosal tunnel
   - Preservation of the ureteral blood supply
   - Creation of a tension-free anastomosis
   - Adequate proximal and distal ureteral fixation
   - Adequate closure of the muscular hiatus
   - Placement of the hiatus posteriorly and medially in the immobile portion of the bladder
   - Avoidance of ureteral torsion, kinking, or J-hooking.
6. The most frequent cause of decreased urine output in the early postoperative period is mild ureteral obstruction secondary to transient edema. Additionally, dehydration resulting from preoperative fasting and supraphysiologic secretion of antidiuretic hormone in response to surgical stress may also contribute.
7. Late ureteral obstruction is most commonly the result of an error in surgical technique including mechanical obstruction or devascularization of the distal ureter.
8. Following surgical treatment of VUR, reflux may persist in the affected ureter or may occur in the contralateral ureter in approximately 2% and in 10–18% of patients, respectively.
9. Reported success rates with Dx/HA for the endoscopic treatment of VUR have been between 76% and 94% after a single injection.
10. Excisional tapering of a megaureter requires careful attention to ureteral blood supply during resection of the redundant ureter and closure of the tapered ureter. Injury to the blood supply may lead to devascularization, fistula, and urinary leakage.

The first successful attempt at surgical correction of vesicoureteral reflux (VUR) was reported by Hutch in 1952.[1] Since that time, multiple surgical, endoscopic, and minimally invasive techniques have been described. Open surgical correction remains the gold standard, with success rates of >98% in most pediatric centers.[2,3] While surgical results are excellent, most young children with reflux are managed medically, and older children with observation. Additionally, increasing numbers of children are managed with endoscopic techniques. Given multiple treatment options, it remains imperative that the urologist understand the potential risks and complications of each.

Nonsurgical Complications

Because primary VUR often resolves, the initial management is typically nonsurgical. Although it is impossible to predict which child will outgrow VUR, the disorder is most likely to resolve in younger children with lower grades of reflux.[4,5] The primary goal of the treatment of VUR, whether medical, surgical, or endoscopic, is to prevent pyelonephritis. Pyelonephritis may lead to reflux nephropathy with subsequent hypertension, poor somatic growth, renal insufficiency, and end-stage renal disease.

Antibiotic prophylaxis has proven effective in preventing urinary tract infection (UTI) in children with VUR.[6–8] Because reflux nephropathy may progress in patients with recurrent UTI, it is imperative to maintain sterile urine with daily antimicrobial prophylaxis.[9] The effectiveness of the use of continuous prophylactic antibiotics in preventing breakthrough UTI is well supported in the literature, especially for dilating grades of VUR.[10] Rates of breakthrough UTI in patients compliant with antibiotic treatment are reported to be as low as <5%.[7,11,12] Certainly, with longer periods of conservative management (5–10 years), the risk of UTI-related morbidity may increase. However, recent studies have brought into question whether continuous prophylactic antibiotics prevent breakthrough renal scarring and therefore affect eventual renal function.[7,13–15] Currently the management of VUR is controversial with no universal agreement. There are multiple factors affecting which treatment option is selected. Even daily antibiotic prophylaxis is called into question, with watchful waiting remaining a valid option.

Unfortunately, despite aggressive medical and surgical management of VUR, reflux nephropathy accounts for 3–25% of cases of end-stage renal disease in children and 10–15% of cases of renal failure in adults.[16–20] Reflux-related complications also increase the risk of pregnancy-related morbidity including UTI, pregnancy-related hypertension, and low birth weight.[21,22]

RISKS OF MEDICAL MANAGEMENT

Some uncertainty exists regarding the ideal antimicrobial prophylaxis for use in this population. The most commonly used antibiotics include sulfamethoxazole-trimethoprim, trimethoprim alone, nitrofurantoin, and amoxicillin for neonates and young infants, in daily doses one-fourth to one-half of treatment doses. Although side effects are lower than with treatment doses, adverse effects are reported.[23] Common side effects of sulfamethoxazole-trimethoprim including allergic skin reactions, nausea, vomiting, and diarrhea are reported in 15–22% of patients.[2] Uncommon adverse effects are neutropenia, thrombocytopenia, and photosensitivity reaction. Stevens-Johnson syndrome, although extremely rare, is the most serious side effect.

Nitrofurantoin suspension may cause gastric upset, nausea, vomiting, rash, and fever. Its foul taste may worsen compliance with treatment. Liver toxicity and interstitial pneumonitis are rare but are reported with the use of nitrofurantoin. The use of the macrocrystal preparation eliminates the foul taste, gastric upset, nausea, and vomiting.

Because fructose is used to prepare drug suspensions, children may be at increased risk of dental caries. As sulfa-based drugs and nitrofurantoin are hepatically metabolized they are contraindicated in children <2 months. For this reason, amoxicillin and cephalexin are used in the first 2 months of life. To date, no data suggest that the use of low-dose antibiotics for urinary prophylaxis is dangerous other than the concern for increased microbial resistance.[24]

Patient and family compliance with respect to daily prophylaxis and follow-up certainly affects successful prevention of pyelonephritis and reflux nephropathy. In a public health system model, compliance rates exceeded 90%.[11] The RIVUR study demonstrated a compliance rate of >75% for administering medications at least 75% of the time and >85% for administering medications at least 50% of the time.[7] However, >34% of patients with reflux in the United States are lost to follow-up.[25]

Current recommendations for patients with unresolved reflux after years of medical management vary, ranging from surgical correction of moderate-grade reflux after 4 years of observation[26] to complete discontinuance of antibiotic prophylaxis and clinical monitoring of patients after 6 or 7 years of age.[27] The American Urological Association (AUA) no longer automatically recommends surgical therapy for unresolved dilating VUR, but recommends escalating therapy for patients who experience breakthrough UTIs (either start daily prophylaxis or proceed with surgical or endoscopic therapy if the UTI occurs while on prophylaxis).[4] In female patients, ongoing VUR may increase the risk of pyelonephritis, especially during pregnancy and with sexual activity.[22,28,29] Therefore, surgical or endoscopic therapy may be warranted in some female patients regardless of VUR grade if the disorder does not resolve.

Bladder Dynamics and Vesicoureteral Reflux

Patients with voiding dysfunction often present with wetting, UTI, and VUR. Treatment of the underlying disease with a combination of bladder retraining, constipation treatment, anticholinergics, and biofeedback frequently eliminates incontinence, UTI, and at times VUR and thus obviates the need for surgical or endoscopic intervention. Normal voiding habits and normal bladder dynamics are essential for successful antireflux surgery. One of the most common problems with failed reimplants is undiagnosed or underestimated bladder disease. This error may have a significant effect on surgical and endoscopic outcomes and also increases the risk of postoperative UTIs. Most cases of

persistent postoperative reflux will likely resolve with the treatment of voiding dysfunction.[30]

Surgical Complications of Ureteral Reimplantation in the Nondilated Ureter

TECHNICAL CONSIDERATIONS

Many different techniques with similar success rates have been described for ureteral reimplantation. The technical aspects of these procedures are discussed elsewhere and are not reviewed here.[31–33] To ensure a successful result, several common principles of ureteral reimplantation must be followed. The most critical point is to provide adequate detrusor backing for the ureter in its submucosal tunnel. As advocated by Hendren,[34] an atraumatic no-touch technique should be employed to mobilize the ureter. Submucosal tunnel lengths should be four to five times the ureteral diameter. Other important technical considerations include the following:

1. Preservation of ureteral blood supply
2. Creation of a tension-free anastomosis
3. Adequate proximal and distal ureteral fixation
4. Adequate closure of the muscular hiatus
5. Placement of the hiatus posteriorly and medially, in the immobile portion of the bladder
6. Avoidance of ureteral torsion, kinking, or J-hooking.

POSTOPERATIVE EVALUATION AND IDENTIFICATION OF COMPLICATIONS

Complications of antireflux surgical procedures may be evident in the immediate postoperative period; however, many complications do not become evident until years after an assumed successful repair. Early complications of antireflux surgical procedures are symptomatic and clinically evident, whereas late complications are often asymptomatic. We typically obtain a renal and bladder ultrasound 4 weeks postoperatively to evaluate for hydronephrosis. Hydroureteronephrosis may be seen as a result of edema at the ureterovesical junction (UVJ) if the image is obtained <4 weeks after the procedure. If significant dilation is noted on the postoperative ultrasound, a diuretic renal scan is obtained to rule out significant obstruction.

We no longer routinely obtain postoperative voiding cystourethrograms (VCUGs) after uncomplicated reimplant procedures at our institution. Although this practice is supported by other surgeons,[35,36] the decision to obtain a postoperative VCUG should be based on the surgeon's experience and individual success rates. The AUA guidelines do not uniformly recommend postoperative VCUG after open surgical repair, but allow the clinical course to affect the final decision.[4] If a VCUG is obtained, it should be performed 3 to 4 months postoperatively to allow for resolution of edema or inflammation at the UVJ. Suppressive antibiotics are continued for 1–3 months postoperatively whether or not the patient had been on antibiotic prophylaxis preoperatively. Renal and bladder ultrasounds are obtained on a yearly basis for 3–4 years to screen for delayed complications of surgical treatment of VUR. Yearly blood pressure measurements and urinalysis are obtained to identify hypertension in children with renal scarring and UTI, respectively.

EARLY COMPLICATIONS

Low Urine Output

Low urine output may be a sign of several different complications of antireflux surgical procedures. The most frequent cause of decreased urine output (<1 mL/kg/hour) after ureteral reimplantation is mild ureteral obstruction secondary to transient edema at the UVJ. Mild dehydration secondary to preoperative fasting and supraphysiologic secretion of antidiuretic hormone in response to surgical stress also contribute to low urine output. This condition generally responds to fluid boluses (10 mL/kg lactated Ringer solution or 0.9% normal saline solution) and resolves ≤4 to 6 hours after the surgical procedure with no long-term sequelae. Dehydration may be avoided with vigorous intraoperative hydration to compensate for fasting and third-space losses.

Profound oliguria and anuria occur infrequently and most commonly in bilateral cases or after surgical correction of reflux in a solitary kidney. In both unilateral and bilateral obstruction, the patient may complain of abdominal or flank pain, nausea, and vomiting. Oliguria or anuria can be a sign of a technical error leading to ureteral obstruction or of severe ureteral or UVJ edema. It may be worsened by bladder spasm or obstruction of the orifices by the balloon of the urethral catheter. Treatment with anticholinergics and deflation of the catheter balloon or catheter removal are useful in differentiating between these factors. Overly aggressive fluid replacement with hypotonic solutions should be avoided because it may lead to hyponatremia. A renal and bladder ultrasound is useful if oliguria persists after volume replacement. Hydroureteronephrosis or urinary extravasation may be evident (Fig. 58.1). These findings may be confirmed with a diuretic renal scan (Fig. 58.2).

Decompression of the upper urinary tract with a temporary percutaneous nephrostomy tube with or without



Figure 58.1 Renal ultrasound scan 2 days after routine ureteral reimplantation shows moderate hydronephrosis. LT LONG KD, left longitudinal kidney.

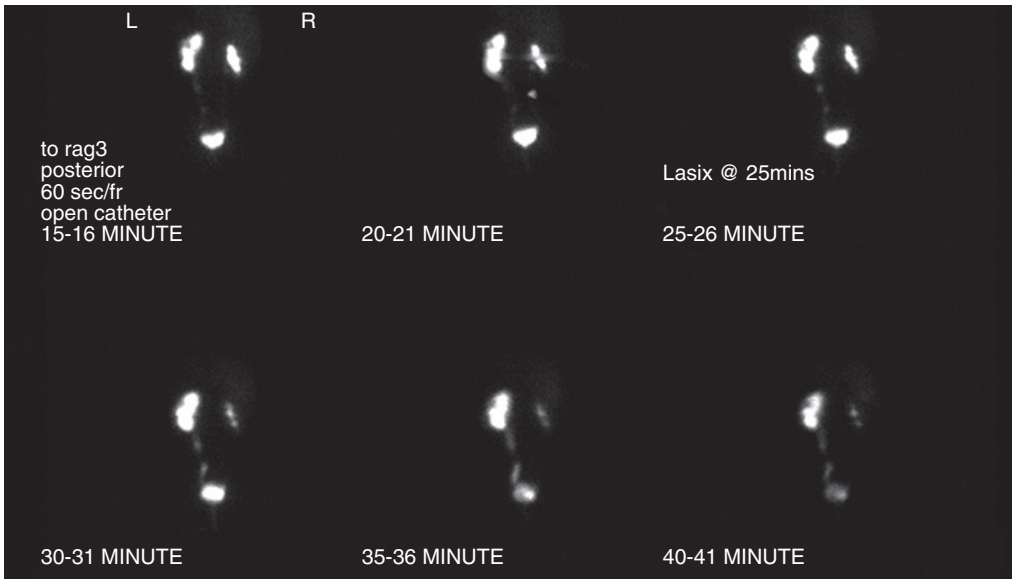


Figure 58.2 Diuretic renal scan confirms obstruction at the ureterovesical junction. This obstruction may be related to edema in the early postoperative period.

ureteral stenting is recommended in cases of ureteral obstruction. We agree with surgeons who advocate early stent internalization to avoid a "dry reimplant."[33] The ability to place a retrograde stent may be limited in the early postoperative period, particularly after a Cohen ureteroneocystostomy. Open retrograde stent placement may rarely become necessary if less invasive percutaneous techniques fail. Stents are generally left in place for 4 to 6 weeks to allow for resolution of edema at the UVJ. The ultimate outcome is usually that of a successful reimplantation. Once the stent is removed, urine output is monitored and serial renal ultrasounds are obtained. If hydroureteronephrosis persists, a diuretic renal scan is obtained and the patient is treated accordingly (see later). In our practice, ureters that are plicated or tapered and the ureter of a solitary kidney are routinely stented at the time of reimplantation.

Postoperative urinary extravasation is an uncommon problem and is usually related to inadequate closure of the detrusorotomy. This complication can be managed conservatively by replacing the urethral catheter for an additional 72 hours. Some surgeons routinely prefer to leave perivesical Penrose or Jackson-Pratt drains after reimplantation, although we have not found this approach to be necessary.

Infections and Voiding Dysfunction

Postoperative febrile UTI and urosepsis may occur after reimplantation. A preoperative urine culture is obtained 5 to 7 days before the surgical procedure. If results of the culture are positive and the patient is asymptomatic, the patient is treated with the appropriate antibiotics. If the patient is asymptomatic, the bladder is inspected cystoscopically to identify signs of inflammation before the incision is made. Inflammation may increase both the difficulty of the surgery and postoperative complications. If the preoperative culture grows unusual or resistant organisms or if a patient is symptomatic, urine culture should be repeated and results should be negative before the surgical procedure is performed. Generally, we postpone the operation to allow the inflammatory response to resolve.

The incidence of recurrent cystitis after successful reimplantation has been reported to be up to 39%, and ≤8% of patients have clinical pyelonephritis.[36–39] Voiding dysfunction may increase the risk of postoperative pyelonephritis after successful reimplantation and should be addressed. Parents should be forewarned of this complication because it may cause severe anxiety in the postoperative period.

Transient voiding dysfunction is common after intravesical ureteral reimplantation. Daytime urge incontinence, nocturnal enuresis, and bladder spasms may continue for several weeks and resolve as bladder inflammation resolves. Patients with significant bladder spasm or pain on urination may require anticholinergic therapy or phenazopyridine hydrochloride, respectively.

Postoperative urinary retention is rare following intravesical reimplantation. However, much concern and controversy exist regarding urinary retention after bilateral extravesical repair. The reported incidence of urinary retention after bilateral extravesical repair varies from 3.2% to >22%.[40–42] In the series reported by Fung and colleagues,[43] urinary retention persisted in 5.2% of their patients at 8 weeks postoperatively, and two patients had prolonged urinary retention and required temporary cutaneous vesicostomy and a catheterizable channel. Nerve-sparing techniques have been described because urinary retention is thought to be the result of neurapraxia related to detrusor nerve manipulation.[44] Using such modifications, the rate of immediate urinary retention was reported to be 2% with no long-term urinary retention or voiding dysfunction.

Following transvesical reimplant, hematuria is expected to persist for several weeks as the detrusor and mucosa heal and as spasms resolve. Meticulous closure of mucosal incisions minimizes this problem. Although rare, retrovesical hematoma may result in ureteral obstruction.[45] To avoid this complication, great care must be taken when the ureter is dissected, particularly in the retroperitoneum.

LATE COMPLICATIONS

Ureteral Obstruction

When prolonged ureteral obstruction occurs postoperatively or when obstruction is identified during routine follow-up, the cause is not typically related to transient edema, as is common in the early postoperative period. Late ureteral obstruction may be associated with abdominal or flank pain, nausea, vomiting, or UTI, or it may be completely asymptomatic.

Late ureteral obstruction is most commonly the result of an error in surgical technique (Fig. 58.3). The most common causes of obstruction are mechanical obstruction and devascularization of the distal ureter. Ureteral obstruction is rare, occurring in <2% of cases.[4,46] Although technical problems may become apparent early in the postoperative period, they are more commonly noted on radiographic examination in an asymptomatic patient. Often these changes are associated with significant loss of renal function.[47,48] It is unlikely that ureteral obstruction diagnosed early in the postoperative period that does not resolve spontaneously or after stent placement or obstruction diagnosed long after the surgical procedure will improve without reoperation.

The diagnosis of obstruction can be made with ultrasound or renal scan. A diuretic renal scan has the additional advantage of estimating the function of the affected kidney. Occasionally, an antegrade nephrostogram or Whitaker study may become necessary to differentiate persistent nonobstructive hydronephrosis from true obstruction (Fig. 58.4).

Devascularization of the distal ureteral segment may lead to ischemia and stricture. Devascularization may be avoided by gentle manipulation of the ureter and cautious use of electrocautery when the ureter is dissected from the detrusor hiatus. Torsion of the reimplanted ureter within the submucosal tunnel can also lead to obstruction. Placement of a traction suture at the ureteral meatus allows for gentler manipulation of the ureter. Additionally, this suture serves as a marker for proper orientation after mobilization of the ureter.

The submucosal tunnel should be created with care to ensure adequate width, length, and hemostasis. Bleeding from the submucosal tunnel can cause ureteral compression and early postoperative obstruction. The submucosal tunnel should allow the ureter to sit freely within it without compression. The distal ureter is anchored to the detrusor muscle with a long-lasting absorbable suture to prevent ureteral retraction. An additional suture may be used to secure the ureter to the detrusor muscle at the level of the hiatus to provide two-point fixation of the ureter at both ends of the submucosal tunnel. The ureter should be approximated to the bladder mucosa with a fine absorbable suture to prevent the uncommon complication of ureteral meatal obstruction.[49]

If the new ureteral hiatus is placed too far laterally on the mobile portion of the bladder, especially when one uses the Leadbetter-Politano technique or other suprahiatal techniques, intermittent ureteral obstruction caused by "J-hooking" and obstruction of the ureter as the bladder fills can result.[50] This diagnosis can be difficult to make because the complication manifests silently and requires upper urinary tract studies with the bladder empty and full. If the obstruction is mild and is identified with only significant bladder filling, these patients can be managed with frequent bladder emptying

Most patients with J-hooking require revisionary surgical procedures. This complication is related to redundancy in the ureter or lateral placement of the hiatus and therefore requires straightening and excision of the redundant ureter or movement of the ureteral hiatus medially onto the fixed portion of the posterior bladder wall.

Ureteral obstruction may also occur with a narrow neohiatus, a hiatal defect that is closed too tightly, or an acute angulation as the ureter enters the submucosal tunnel (commonly the result of a prominent lip of tissue at the detrusor hiatus). Kinking and narrowing may be avoided by incising some detrusor fibers at the inferior portion of the neohiatus to create a trough for the ureter.[33,51]

If the original hiatus is used, the defect must be closed carefully to ensure adequate mobility of the ureter within the detrusor portion of the tunnel. The hiatus should be left wide enough to allow passage of a tonsil clamp or similarly sized instrument adjacent to the ureter. In this manner, the hiatus is of sufficient caliber to prevent constriction but is narrow enough to prevent formation of a postoperative

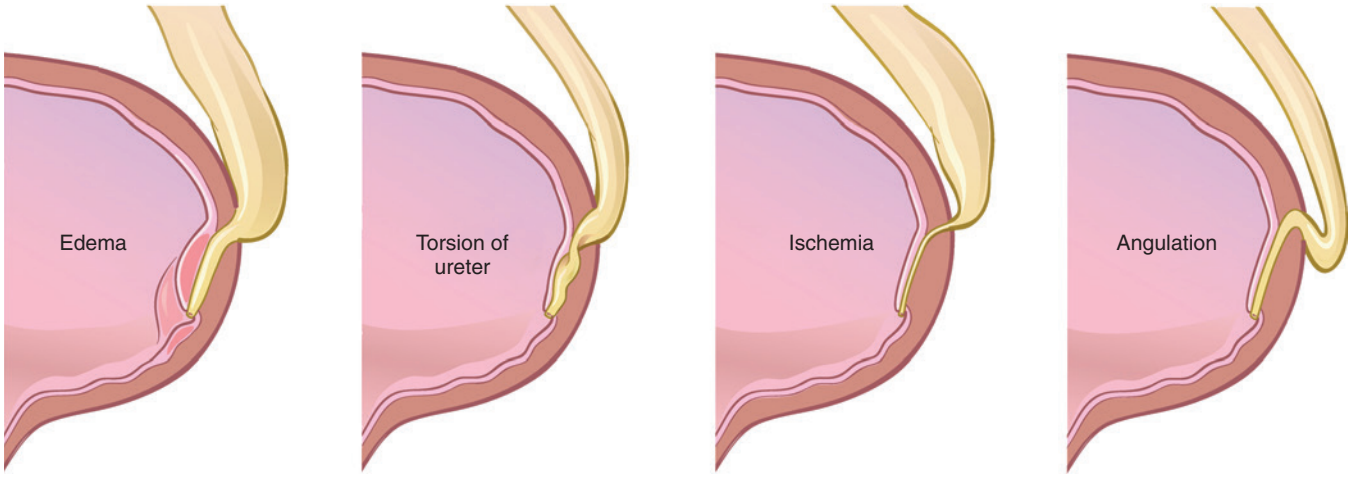


Figure 58.3 Various errors in technique may result in ureteral obstruction.

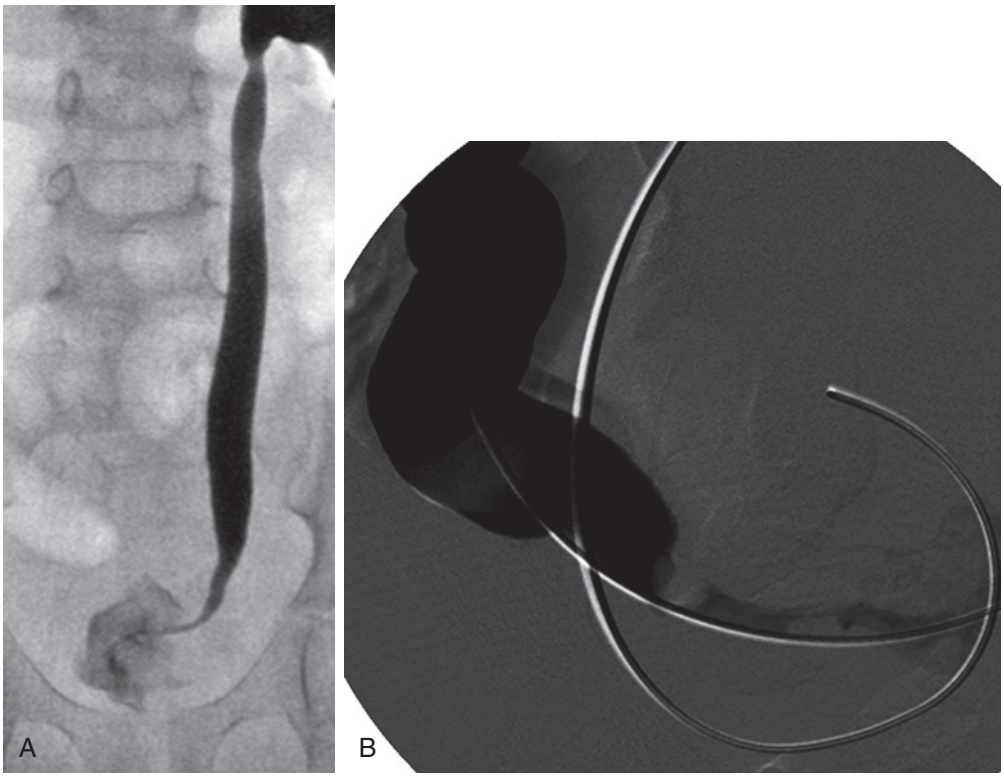


Figure 58.4 A, Antegrade nephrostogram shows narrowing at the ureterovesical junction. This condition was secondary to edema and resolved. B, Antegrade nephrostogram demonstrates massive dilation of the proximal ureter. The obstruction resulted from ischemia and required a tapered reimplant with a psoas hitch.

diverticulum. The incidence of postoperative diverticulum has been reported to be ≤17% following a Cohen reimplantation. Diverticula have been blamed for both recurrent reflux and postoperative obstruction.[52]

Care must be taken to pass the ureter under direct vision during transvesical procedures that require creation of a neohiatus, to avoid passage of the ureter into and out of the peritoneal cavity. Late ureteral obstruction has been attributed to adhesions within the transperitoneal course of the ureter, placement of the ureter through bowel segments, and placement of the ureter through the broad ligament.[47,53,54] Blunt dissection of the peritoneum off the posterior bladder wall and passage of a right angle through the neohiatus under direct vision should help prevent these complications.

In male patients, care must be taken to avoid injury to the vas deferens during transvesical mobilization of the ureter. Additionally, ureteral obstruction may occur if the hiatus is moved superiorly within the bladder and the ureter is not moved anterior to the vas, with resulting acute angulation.

POSTOPERATIVE REFLUX

Ipsilateral Reflux

Following surgical treatment of VUR, reflux may persist in the affected ureter or may occur in the contralateral ureter in approximately 2% and up to 32% of patients, respectively.[2,55] Significant evidence indicates that persistent reflux, identified on postoperative VCUG, may resolve without intervention because it may be caused by a transient voiding dysfunction and inflammation. Persistent postoperative VUR is reported to resolve spontaneously in 24% to 100% of cases.[55–61] Because the rate of postoperative resolution of persistent postoperative reflux is so high, our practice is to prescribe long-term prophylactic antibiotics for these patients. A repeat VCUG is delayed for approximately 1 year.

Persistent reflux is most commonly attributed to inadequate tunnel length, but it may also result from persistent inflammation at the submucosal tunnel (Fig. 58.5). An infrequent cause of postoperative reflux is the development of a ureterovesical fistula.[62,63] Formation of a ureterovesical fistula is attributed to entrapment and devascularization of the intravesical portion of the ureter with suture used to close the bladder mucosa. This complication can usually be recognized on cystoscopy and requires reoperation with resection of the ureter distal to the fistula with remobilization of the ureter and reimplantation with an appropriate tunnel. Bladder diverticulum at the hiatus may prevent adequate tunnel length and may result in persistent reflux.

Contralateral Reflux

The incidence of contralateral reflux after unilateral reimplantation has been reported to be between 0.6% and 32%, with more recent studies reporting an incidence of 10–18%.[54,64–68] Spontaneous resolution has been reported in 61–98% of cases with a minimum of 3 years of follow-up, and most investigators recommend observation while the patient is receiving prophylactic antibiotics as an initial

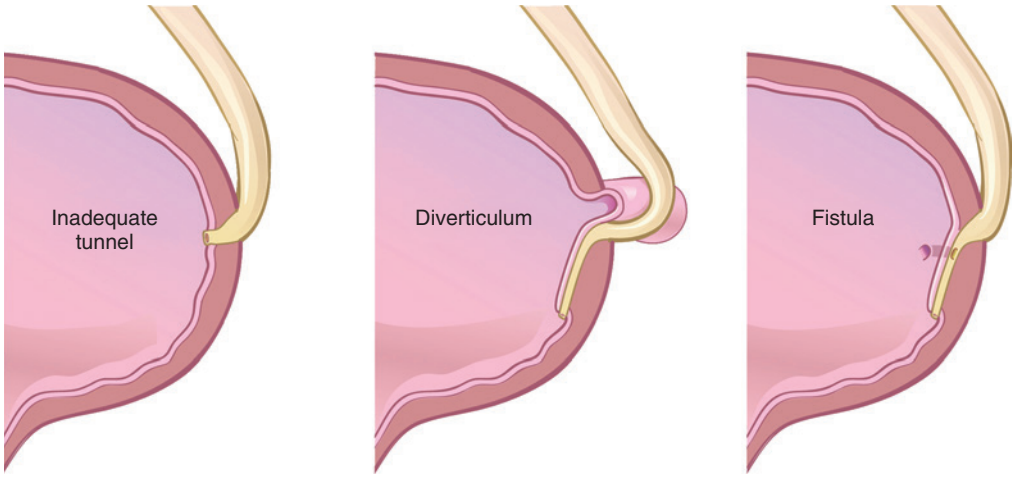


Figure 58.5 Potential technical errors that can result in persistent reflux.

treatment measure.[34,55,64,65,69] Additionally, treatment of voiding dysfunction, if present, with behavioral modification, medical therapy, or both is indicated during this period. In children with breakthrough UTIs, correction of postoperative reflux should be considered. Although most cases of postoperative contralateral reflux resolve spontaneously, this potential risk should be discussed preoperatively.

Several reasons have been proposed for the development of contralateral reflux. Warren and colleagues[55] suggested that patients with an abnormal shape or position of the ureter were at greatest risk. Other theories to explain contralateral VUR include operative trigonal distortion or a pop-off mechanism; however, these theories have been challenged.[67,70–74] In a review of 107 patients, Noe[75] identified two possible contributors to contralateral VUR: (1) age at initial operation, which correlates with a smaller number of cystograms and fewer opportunities to identify contralateral VUR; and (2) the presence of dysfunctional voiding. Additionally, low observed versus predicted bladder capacity may be associated with postoperative contralateral VUR.[68] On follow-up most postoperative contralateral VUR will resolve spontaneously with a benign clinical course.[68] While some believe it is not warranted, we tend to perform bilateral reimplants in any patient with a history of bilateral VUR even after unilateral spontaneous resolution.

MANAGING THE FAILED REIMPLANT

A reoperative surgical procedure after failed (persistent reflux or obstruction) ureteral reimplantation is often difficult and involves longer operative times. Surgical planes are challenging, and the risk of future complications related to devascularization and contralateral ureteral injury is increased. More aggressive extravesical mobilization and the use of a psoas hitch or a Boari flap are more likely to become necessary to prevent reflux successfully in repeat surgical procedures.

Patients whose initial reimplant fails should receive long-term antibiotic prophylaxis. Reevaluation of reflux should include renal and bladder ultrasound, VCUG, and diuretic renal scan. Additional studies including a Whitaker test may be necessary in cases of equivocal obstruction. We believe that all children with persistent reflux after reimplantation should undergo urodynamic evaluation.

In a child with postoperative obstruction, reoperation should be delayed for ≥3 to 6 months to allow the distal ureter to reestablish sufficient vascularity. Diversion with a percutaneous nephrostomy tube decompresses the collecting system and permits repeat investigation with a Whitaker test if necessary.

If the decision is made to reoperate on a child with persistent reflux or obstruction, the surgeon must individualize the management of each patient and be prepared with a variety of reconstructive options. Preoperative cystoscopy may aid in identifying a short mucosal tunnel, diverticulum, or fistula as the cause of persistent VUR. Retrograde ureteropyelography or intravenous urography can provide useful information about the severity of ischemic changes or angulation of the distal ureter if an antegrade study cannot be performed. Occasionally, the ureteral orifice may be completely obliterated by severe scarring.[47]

Various open procedures have been used for reoperative ureteral reimplantation including the Cohen, Leadbetter-Politano, Paquin, and a combined intravesical-extravesical approach, each with good results.[42,76–78] We have usually been able to mobilize the ureter adequately through the Pfannenstiel incision, although a vertical midline incision may also be employed for more exposure. The ureter must be carefully mobilized, to preserve all tissue surrounding the ureter. Sacrificing the gonadal vessels to improve the blood supply to the distal ureter is occasionally necessary and has been suggested by some surgeons. If the ureter is dilated >1 cm, it should be tapered to allow an adequate submucosal tunnel. A psoas hitch may be necessary when the ureter is short or when a longer tunnel for a tapered reimplant is necessary.[77,79] In rare cases, bowel interposition, transureteroureterostomy, or transureteropyelostomy may be necessary.[77,80] Alternatively, robotic/laparoscopic approaches have been shown to have similar success rates to open repair of failed previous antireflux surgery.[81,82] Percutaneous balloon dilation of UVJ strictures following reimplantation of the ureter has been described in a limited number of patients with favorable short-term outcomes.[83,84]

Dextranomer/hyaluronic acid (Dx/HA) has been used as an alternative to reoperation in patients with persistent postoperative VUR.[85–87] In each series, patients identified with postoperative VUR were initially observed. During the period of observation, Jung and colleagues[86] maintained patients on antibiotic prophylaxis and treated voiding dysfunction in those affected. Seventy to 80% of the renal units injected had complete resolution of reflux after one injection. A second injection was successful in two-thirds of the patients in the series by Jung and colleagues.[86] No complications resulting from injections were reported.

Complications of Endoscopic Correction of Vesicoureteral Reflux

Endoscopic therapy of VUR was first introduced in 1984.[88] This technique has become increasingly popular since the introduction of Dx/HA (Deflux, Q-Med Scandinavia), which was approved for use in the United States in 2001. Dx/HA is indicated for the treatment of grade II to IV VUR. The use of this agent is contraindicated in patients with active voiding dysfunction, UTI, ureters with associated Hutch diverticulum, ureteroceles, and nonfunctioning kidneys.[89] Success rates, defined as a lack of VUR on postoperative VCUG, after a single injection are reported to be between 76% and 94%.[90,91] However, these successes vary based on the experience of the endoscopist, the grade of reflux, the underlying bladder disease, and ureteral anomalies such as duplications and ectopia.[92–95] In duplicated systems, the success rate after one injection is reported to be approximately 70%.[96] The incidence of contralateral reflux following endoscopic injection with Dx/HA ranges from 4.5% to 12.5%.[91,97,98]

In cases of failed Dx/HA injection, the material appears to migrate away from the subureteric orifice or migrates to the extravesical space or along the periureteral sheath (Fig. 58.6). Although this issue is controversial, volume reduction may occur in time and may lead to failure.[89,99,100] In the meta-analysis by Elder and associates,[90,101] repeat therapy was successful in 68% of ureters, whereas Elmore and colleagues[100] reported a success rate in 89% of ureters undergoing second injections. The AUA guidelines recommend routine postoperative VCUG after endoscopic injection of bulking agents to ensure resolution of VUR.[4]

Open ureteral reimplantation after failed injection is more difficult than is a primary open reimplantation procedure and may be related to granuloma formation secondary to injection. In our practice, higher rates of obstruction have been noted after open reimplantation for failed injection therapy.[102] We therefore leave a ureteral stent in place in these children. In addition to persistence of reflux and new contralateral reflux, extravesical ureteral obstruction has also been reported (Fig. 58.7).[103] Salvage open and robotic extravesical approaches to persistent VUR after failed injection therapy have been described with some success.[82,104,105] Given the relatively recent introduction of injection therapy, it remains difficult to comment on long-term complications; however, the Swedish Reflux Study demonstrated a 20% rate of recurrent dilating reflux 2 years after initial Dx/HA injection.[106]

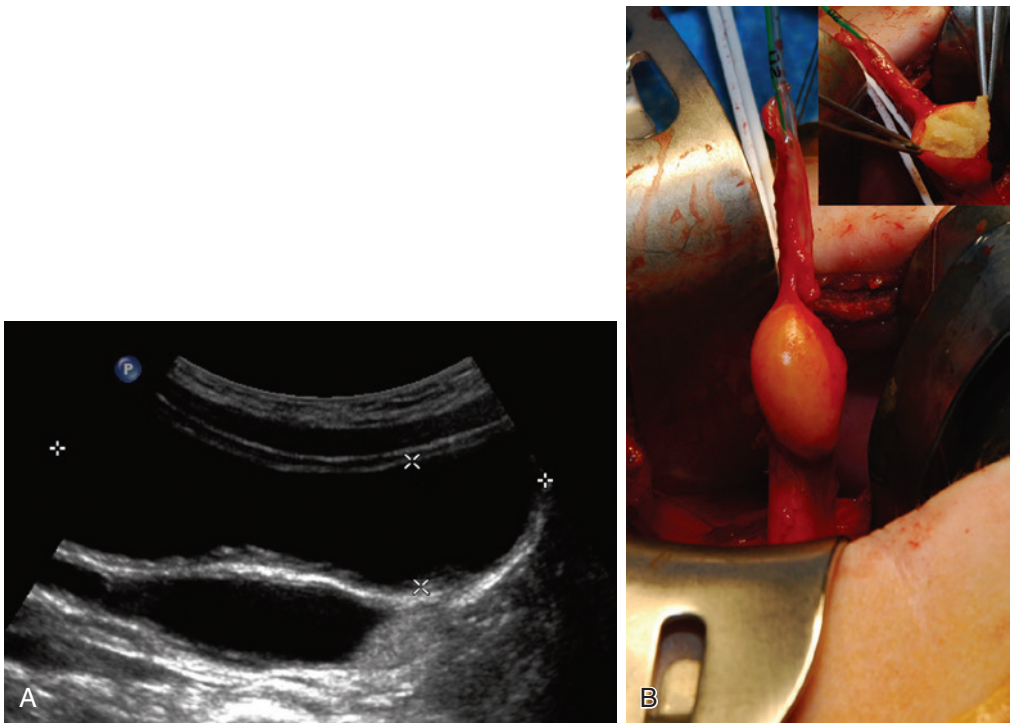


Figure 58.6 Migration of dextranomer/hyaluronic acid used in the treatment of vesicoureteral reflux. A, Hyperechoic material at the distal end of the ureter. B, Encapsulated migrated material consistent with ultrasound findings. The *inset* shows the granular makeup of dextranomer/hyaluronic acid.

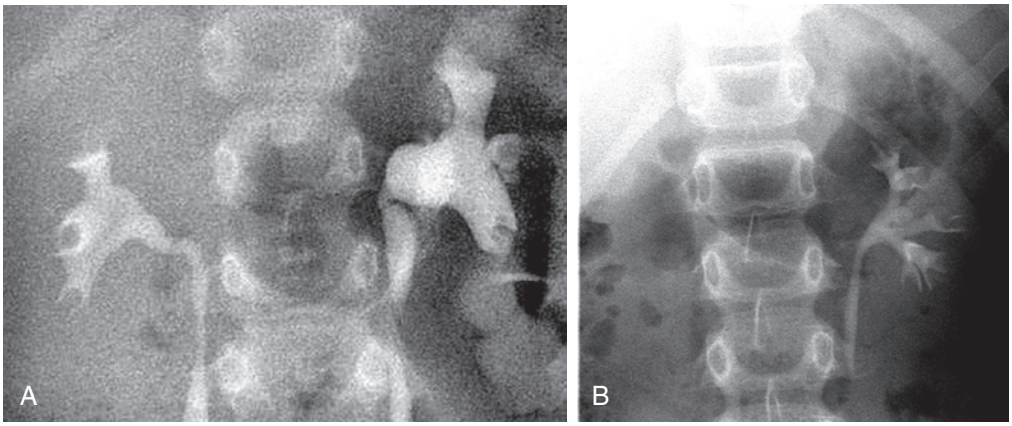


Figure 58.7 A, Preoperative voiding cystourethrograms with bilateral VUR after endoscopic therapy. B, Postoperative voiding cystourethrograms with resolution of right VUR and minimal improvement of left VUR. The dextranomer/hyaluronic acid "mound" was not sonographically identified on the left.

Surgical Complications of Laparoscopic/Robotic Reimplant

Both extravesical and transvesical laparoscopic and robotic ureteral reimplantation procedures have been described. The most common minimally invasive approach to VUR is the robotic-assisted laparoscopic extravesical ureteral reimplant.[107] Some significant series have reported success rates ranging from 77% to 100%.[82,105,108–110] Complication rates for robotic-assisted extravesical reimplantation are similar to the traditional open extravesical reimplantation, such as those for transient urinary retention (0–12%) and contralateral reflux (6–23%).[81,82,105,108–110] Pelvic plexus visualization has allowed for a nerve-sparing technique that is reported to decrease the rate of postoperative urinary retention and voiding dysfunction following bilateral extravesical robotic-assisted laparoscopic ureteral reimplantation.[110] The robotic approach has been expanded to ureters requiring tapering or dismembering and ureters with associated duplication and diverticula.[81,111,112] Complications unique to robotic surgery include potential conversion to an open procedure, longer surgery times,[108,109] intraperitoneal urine leak,[110] and intraabdominal organ injuries or ileus given the intraperitoneal approach.[82] Advantages may include shorter length of stay[81,107–109] and decreased narcotic use compared to open surgery.[109]

Surgical Complications of Megaureter Repair

Some controversy exists regarding the timing of megaureter repair. Today, many children with megaureters present as asymptomatic neonates referred for evaluation of antenatal hydroureteronephrosis.[113,114] Surgical treatment of the refluxing megaureter and of the nonrefluxing, nonobstructed megaureter is often unnecessary. Improvement in high-grade reflux occurs commonly in the first year of life.[2,4] The megaureter that is neither refluxing nor obstructed often maintains normal function and reverts to normal caliber in time.[115] Obstructed refluxing megaureters often require surgical intervention. However, the treatment of obstructed nonrefluxing megaureters remains controversial and can also include endoscopic management with stenting and early refluxing reimplants.[103,116–120]

Regardless of the timing or indications for megaureter repair, the procedure is technically challenging and carries a significantly greater risk of postoperative complications than in the case of a nondilated ureter.[121] Reconstruction of the megaureter may be achieved using an excisional technique described by Hendren[122] or by one of the imbricating methods, most commonly those described by Starr[123] and Kalicinski and colleagues.[124]

Excisional tapering of a megaureter requires careful attention to ureteral blood supply during resection of the redundant ureter and closure of the tapered ureter. Injury to the vascular supply of the ureter may lead to devascularization, obstruction, fistula, and urinary leakage. Inherent ureteral characteristics such as increased collagen and altered smooth muscle of the distal ureter may also contribute to surgical failure.[121,125,126] Reported success rates for excisional tapering range from 74% to 90%.[127–131]

Tapering should be performed when a submucosal tunnel long enough to fulfill the 5:1 rule of tunnel length to ureteral diameter cannot be achieved. Hendren's series[122] remains the largest reported, and the complications are well detailed.[115,127] Of 160 patients with primary and secondary megaureter, 14 had transient obstruction requiring percutaneous nephrostomy tubes, 11 had obstruction requiring reoperation, and eight had postoperative reflux, for an overall success rate of 88%.

Success rates for imbricated techniques are slightly better and are reported to be 93–95%, with lower rates of vascular injury when compared with excisional techniques.[117,124,125,130,132] The slightly better success rates in the imbricated group may be a consequence of selection bias because plication was limited to ureters with smaller diameters in some studies.[125] Persistent reflux, seen in both the Kalicinski and Starr techniques, is most likely the result of failure of reimplantation rather than failure to narrow the ureter. The plicated ureter is bulky, a characteristic that renders creation of a submucosal tunnel more difficult.[133] One of the greatest advantages of folding and plication

techniques is that these procedures can be performed on moderately dilated ureters entirely intravesically.

Patients in whom megaureter repair has failed and patients with iatrogenic megaureter secondary to obstruction after ureteral reimplantation must be carefully evaluated for factors contributing to treatment failure such as voiding dysfunction or poor bladder compliance. Patients with new or persistent VUR after megaureter repair should be given prophylactic antibiotics because reflux may resolve with observation.

In cases of obstruction, a percutaneous nephrostomy tube should be placed. Occasionally, the obstruction resolves with diminishing edema. Upper urinary tract drainage with the nephrostomy tube allows for antegrade radiographic examinations, Whitaker tests, and time for healing before a corrective surgical procedure is attempted. Altered ureteral histologic features may limit the ureter's capacity for proper peristalsis. As in any reimplantation procedure, bladder dynamics must be examined. In some cases clean intermittent catheterization, anticholinergics, or frequent bladder emptying may become necessary.

Surgical Complications of Ureterocele Repair

A *ureterocele* is a cystic dilation of the terminal ureter within the bladder, urethra, or both that creates diagnostic and therapeutic dilemmas once it is identified. Management of ureterocele varies and depends on the presence of obstruction, reflux, and incontinence, as well as the function of the affected kidney or renal moiety. Ureteroceles occur most commonly in white patients and are four to six times more frequent in girls than in boys.[134] Ectopic ureteroceles are four times more common than are intravesical ureteroceles.[135]

Today, ureteroceles are more likely to be diagnosed based on prenatal ultrasonography rather than on UTI. Hydronephrosis and dysplasia of the upper pole moiety are commonly associated with a ureterocele.[133] Rarely, ureteroceles may manifest with bladder outlet obstruction because ectopic ureteroceles can prolapse. Ureteroceles found in adults are usually intravesical and are associated with a single collecting system. Adult ureteroceles may be acquired rather than congenital, as in children. Function of the affected kidney is less likely to be impaired in an adult.[136]

The diagnosis of ureterocele may be difficult. A ureterocele may be collapsed and thus not visible on an ultrasound scan if the bladder is overfilled. If the bladder is underfilled, a large ureterocele may fill the entire bladder and give the impression of a partially filled bladder. A VCUG should be obtained to evaluate for VUR in association with the ureterocele. Reflux to the ipsilateral lower pole occurs in approximately 50% of cases, and contralateral reflux occurs in approximately 25%. This complication is likely the result of distortion of the bladder base by the ureterocele.[137] Occasionally, a ureterocele may evert during VCUG and resemble a diverticulum. Nuclear renal scans are useful to evaluate the function of the moiety associated with the ureterocele and that of other moieties. Poorly functioning moieties may not be worth salvaging.

Once the ureterocele has been radiographically evaluated, treatments range from endoscopic decompression to complex reconstruction.[138] Nonoperative management has also been advocated in cases involving nonobstructed duplex systems with relatively good preservation of renal function, associated multicystic dysplastic moieties, or completely nonfunctioning upper pole moieties.[139] Additionally, watchful waiting may have a role in cases of prenatally detected ureteroceles without bladder outlet obstruction, ipsilateral lower moiety obstruction, and ipsilateral lower moiety VUR less than grade IV.[140]

It is beyond the scope of this chapter to discuss each of the different management techniques; however, the complications encountered are directly related to the treatment options selected. Endoscopic incision or puncture is simple and minimally invasive. It typically requires a short anesthetic regimen and usually can be performed as an outpatient procedure. The procedure has been reported to offer definitive therapy in ≤93% of patients with intravesical ureteroceles.[141,142] No consensus exists on the effectiveness of technique for treating ectopic ureteroceles; however, the watering can technique of endoscopic puncture may lead to less de novo VUR compared to endoscopic incision.[143] Although it may not be curative, incision may relieve obstruction of both the involved and uninvolved moieties and may thus prevent further loss of function and UTI.

If incision does not result in a cure, it allows the delay of definitive treatment until the child has grown. Additionally, the decompressed system may be easier to reconstruct.[144–146] Other investigators have argued that this approach may commit the child to future lower urinary tract reconstruction.[147] Despite controversy, investigators agree that endoscopic puncture of an ectopic ureterocele is indicated for patients with uncontrolled sepsis, azotemia, and bladder outlet obstruction. New reflux may be created in 28–47% of patients as a consequence of ureterocele incision or puncture, and the procedure may fail to decompress the involved moiety in 10–25% of cases.[137,141–143] Postoperatively, the ureterocele may prolapse and urinary retention may occur in ≤10% of patients.[146]

The traditional upper urinary tract approach for ureteroceles associated with a duplicated collecting system and minimal function of the upper pole segment is partial nephrectomy with subtotal removal of the upper pole ureter and ureterocele aspiration. This approach seems to be decreasing with the widespread acceptance of ureterocele incision. Complications of upper pole heminephrectomy include inadvertent ligation of branch vessels to the lower pole resulting in devascularization. Additionally, traction on the lower pole of the kidney may lead to intimal injury and thrombosis of lower pole vessels. Consequently, significant atrophy of the lower pole occurs in 7–10% of cases.[148,149] Careful handling and the use of topical papaverine (30 mg/mL) to prevent vasospasm minimize this complication. Additional complications include prolonged urine leak as a result of entrance into the lower pole collecting system, hemorrhage, and new-onset lower pole VUR.

Complete reconstruction of the ureterocele includes partial nephrectomy, excision of the ureterocele, and reimplantation of the lower pole ureter in patients with a nonfunctioning upper pole or ureterocelectomy and a common sheath reimplant with or without tapering in patients with preservable function in the upper pole.

Ureteral reimplantation associated with a ureterocele is more difficult than is uncomplicated reimplantation and is associated with higher failure rates. To increase the chance of success, our recommendation is to create the tunnel for reimplantation above the area of ureterocele excision. This technique allows normal muscle backing for the reimplanted ureter and precludes working in the area of the reconstructed bladder base or marsupialized ureterocele. Success rates for reimplantation of single system ureteroceles can approach those of uncomplicated reimplantation procedures.

Other potential complications of ureterocele excision include bladder neck injury, urinary incontinence, bladder diverticulum, vesicovaginal fistula, and urethrocutaneous fistula. These complications may be avoided with careful dissection of the posterior wall of the ureterocele from the bladder with approximation of the bladder musculature. The surgeon must be meticulous in any dissection near the bladder neck. Following excision of the ureterocele it is imperative to be certain there is no residual lip of tissue distally that may result in bladder outlet obstruction.

Robotic approaches have been described for partial nephrectomy in children with duplicated collecting systems, and early studies demonstrate similar complication rates to those of open surgery.[150–152]

Conclusions

Ureteral reimplantation of a normal-caliber ureter into a normal bladder can be accomplished successfully with minimal complications. Newer endoscopic techniques are also successful and have few associated complications; long-term effectiveness of endoscopic techniques is unknown. Robotic approaches to ureteral reimplantation approach similar effectiveness and complication rates. Successful outcomes depend on thorough preoperative evaluation of bladder dynamics and meticulous surgical technique. Careful postoperative evaluation allows early recognition and treatment of the uncommon complications.

References

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Chapter 58 Questions

1. What should be considered in the use of prophylactic antibiotics for patients with vesicoureteral reflux?
   a. Prophylactic antibiotics decrease the rate of febrile urinary tract infections
   b. Prophylactic antibiotics decrease the rate of new renal scarring
   c. Prophylactic antibiotics are recommended in all patients with vesicoureteral reflux
   d. Sulfa-based antibiotics can be given during the first 2 months of life
   e. Nitrofurantoin can be given during the first 2 months of life

2. What does successful ureteral reimplantation require?
   a. A submucosal tunnel length two times the diameter of the ureter
   b. No need for ureteral fixation (proximally or distally) within the mucosal tunnel
   c. Preservation of the ureteral blood supply
   d. Placement of the hiatus posterior and lateral in the bladder with an adequate J-shaped curve to the submucosal tunnel
   e. Minimal closure of the muscular hiatus

3. Which of the following statements about postoperative contralateral vesicoureteral reflux is true?
   a. It occurs only after robotic-assisted laparoscopic extravesical ureteral reimplantation
   b. It never occurs after endoscopic therapy
   c. It occurs more frequently in older patients
   d. It often resolves spontaneously
   e. It requires immediate surgical correction

4. Which of the following statements about surgical therapy for megaureter is true?
   a. All megaureters eventually require operation
   b. Excisional tapering and imbrication demonstrate the same complication rates
   c. It always requires careful attention to the vascular supply of the distal ureter
   d. Persistent vesicoureteral reflux after megaureter reimplantation never spontaneously resolves
   e. Voiding dysfunction does not play a role in persistent vesicoureteral reflux after megaureter reimplantation

5. Robotic-assisted laparoscopic extravesical ureteral reimplantation can be considered for which of the following patients?
   a. 8-year-old female with bilateral grade IV vesicoureteral reflux and associated febrile urinary tract infections
   b. 5-year-old male with a refluxing megaureter and associated febrile urinary tract infections that may require tapering
   c. 3-year-old female with left lower pole grade III vesicoureteral reflux and associated febrile urinary tract infections
   d. 10-year-old female with persistent grade II vesicoureteral reflux and associated febrile urinary tract infections after failed injection therapy
   e. All of the above

6. Which of the following statements regarding ureteroceles is true?
   a. It is common to have hydronephrosis and dysplasia of the associated lower pole moiety
   b. There is a low likelihood of reflux in the ipsilateral lower pole
   c. All ureteroceles require operative intervention
   d. Ureteral reimplantation with an associated ureterocele has higher failure rates and is more difficult
   e. Tunnel creation for reimplantation should be made over the area of ureterocele excision

7. Complications unique to robotic-assisted laparoscopic ureteral reimplantation include all of the following, EXCEPT:
   a. Longer surgery times
   b. Intraperitoneal urine leak
   c. Ileus
   d. Postoperative urinary retention
   e. Intraabdominal organ injury

8. Success of endoscopic injection of bulking agents depends on all of the following, EXCEPT:
   a. Experience of the endoscopist
   b. Grade of reflux
   c. Associated voiding dysfunction
   d. Duplicated systems
   e. Number of prior urinary tract infections

9. Which of the following statements for management of postoperative obstruction following surgical correction of reflux is true?
   a. Reoperation should be performed immediately upon identification
   b. Only open revision is recommended (not endoscopic or robotic)
   c. Late ureteral obstruction is most commonly the result of an error in surgical technique
   d. Ureteral obstruction is always symptomatic
   e. Symptomatic ureteral obstruction should initially be managed with endoscopic retrograde placement of a ureteral stent

10. Treatment options for vesicoureteral reflux include:
    a. Watchful waiting
    b. Prophylactic antibiotics
    c. Ureteral reimplantation (open or robotic-assisted laparoscopic)
    d. Endoscopic injection of bulking agents
    e. All of the above

Case Studies

CASE 1

A 3-year-old girl presents with a history of left grade III vesicoureteral reflux and resolved right grade II vesicoureteral reflux with recurrent febrile urinary tract infections requiring hospitalization and intravenous antibiotics while compliant on prophylactic antibiotics.

1. What intervention would you not recommend at this point?
   a. Open left intravesical vesicoureteral reimplantation
   b. Open bilateral intravesical vesicoureteral reimplantation
   c. Bilateral robotic-assisted laparoscopic extravesical ureteral reimplantation
   d. Bilateral endoscopic injection therapy
   e. Investigation for associated dysfunctional voiding

The parents are interested in correction of the VUR, and she undergoes a bilateral Cohen ureteral reimplantation without ureteral stent placement. The next morning she is noted to have low urine output and decreased oral intake, but denies flank pain, nausea, or emesis. Creatinine is stable.

2. What is the most appropriate intervention at this time?
   a. Observation
   b. Increased intravenous fluids
   c. Renal bladder ultrasound
   d. Diuretic renal scan
   e. Cystoscopy and retrograde bilateral ureteral stent placement

With aggressive fluid administration her oliguria resolves and oral intake improves. She is discharged on postoperative day two on prophylactic antibiotics. On her postoperative follow-up at 1 month, renal bladder ultrasound does not demonstrate any hydroureteronephrosis and her prophylactic antibiotics are stopped 3 months after surgery. She presents 12 months after surgery, with recurrent episodes of pyelonephritis.

3. What is the most appropriate intervention at this time?
   a. Restart prophylactic antibiotics
   b. Repeat renal bladder ultrasound
   c. Repeat voiding cystourethrogram
   d. Investigate for dysfunctional voiding
   e. All of the above

CASE 2

A 5-year-old girl with a history of bilateral, grade II VUR diagnosed after an episode of pyelonephritis when she was 2 years old underwent bilateral endoscopic therapy with dextranomer/hyaluronic acid (Dx/HA) after several febrile urinary tract infections while on antibiotic prophylaxis. She was discharged on the day of surgery and was maintained on prophylactic antibiotics. A voiding cystourethrogram performed 3 months after the procedure demonstrated persistent grade II, bilateral VUR, and she was maintained on prophylactic antibiotics. She continued to have recurrent febrile urinary tract infections while on prophylactic antibiotics postprocedure.

1. What do the AUA guidelines state regarding postprocedure voiding cystourethrograms?
   a. Postoperative voiding cystography may be performed following open ureteral reimplantation
   b. Postoperative voiding cystography must be performed following open ureteral reimplantation
   c. Postoperative voiding cystography following endoscopic injection of bulking agent is recommended
   d. Postoperative voiding cystography must be performed following robotic-assisted laparoscopic ureteral reimplantation
   e. a and c

2. What are the treatment options for failed injection therapy for VUR treatment?
   a. Salvage open ureteral reimplantation
   b. Salvage robotic ureteral reimplantation
   c. Repeat injection
   d. Evaluation for voiding dysfunction
   e. All of the above

3. For whom is the use of Dx/HA contraindicated?
   a. Patients with grade IV vesicoureteral reflux
   b. Patients with bilateral vesicoureteral reflux
   c. Patients with failed open reimplantation
   d. Patients with active voiding dysfunction
   e. Patients with duplicated systems

Answers

1. **a.** Antibiotic prophylaxis has proven effective in preventing urinary tract infection (UTI) in children with vesicoureteral reflux (VUR). Because reflux nephropathy may progress in patients with recurrent UTI, it is imperative to maintain sterile urine with daily antimicrobial prophylaxis. The effectiveness of the use of continuous prophylactic antibiotics in preventing breakthrough UTI is well supported in the literature, especially for dilating grades of VUR. Rates of breakthrough UTI in patients compliant with antibiotic treatment are reported to be as low as <5%. Certainly, with longer periods of conservative management (5–10 years), the risk of UTI-related morbidity may increase. However, recent studies have brought into question whether continuous prophylactic antibiotics prevent breakthrough renal scarring and therefore affect eventual renal function. Currently the management of VUR is controversial with no universal agreement. There are multiple factors effecting which treatment option is selected. Even daily antibiotic prophylaxis is called into question, with watchful waiting remaining a valid option. Sulfa-based drugs and nitrofurantoin are contraindicated in children <2 months old because these drugs are hepatically metabolized. For this reason, amoxicillin and cephalexin are used in the first 2 months of life.

2. **c.** Successful reimplantation requires preservation of the ureteral blood supply, a submucosal tunnel four or five times the diameter of the ureter, proximal and distal ureteral fixation of the ureter within the mucosal tunnel, placement of the hiatus posterior and medial in the immobile portion of the bladder, and a muscular hiatus sufficiently wide for the ureter but not wide enough to allow for a diverticulum.
3. **d.** Contralateral reflux often resolves spontaneously and should be monitored without any need for immediate revision surgery. Prophylactic antibiotics are usually administered until the reflux resolves. Contralateral vesicoureteral reflux (VUR) may be related to trigonal distortion, young age at initial operation, which correlates with fewer cystograms and fewer opportunities to identify contralateral VUR, the presence of dysfunctional voiding, and bladder capacity. It may occur after open, robotic, and endoscopic correction.
4. **c.** Surgical treatment of the refluxing megaureter and of the nonrefluxing, nonobstructed megaureter is often unnecessary because improvement occurs commonly in the first year of life. When surgery is necessary, it is imperative to maintain the vascular supply of the distal ureter. Megaureters may be tapered or plicated at the time of reimplantation. Success rates for imbricated techniques are slightly better and are reported to be 93–95%, with lower rates of vascular injury when compared with excisional techniques. The slightly better success rates in the imbricated group may be a consequence of selection bias because plication was limited to ureters with smaller diameters in some studies. Patients in whom megaureter repair has failed and patients with iatrogenic megaureter secondary to obstruction after ureteral reimplantation must be carefully evaluated for factors contributing to treatment failure such as voiding dysfunction or poor bladder compliance. Patients with new or persistent VUR after megaureter repair should be given prophylactic antibiotics because reflux may resolve with observation.
5. **e.** Pelvic plexus visualization has allowed for a nerve-sparing technique that is reported to decrease the rate of postoperative urinary retention and voiding dysfunction following bilateral extravesical robotic-assisted laparoscopic ureteral reimplantation. The robotic approach has been expanded to ureters requiring tapering or dismembering and ureters with associated duplication and diverticula. Salvage open and robotic extravesical approaches to persistent VUR after failed injection therapy have been described with some success. Robotic/laparoscopic approaches have been shown to have similar success rates to open repair of failed previous antireflux surgery.
6. **d.** Hydronephrosis and dysplasia of the upper pole moiety are commonly associated with a ureterocele. Reflux to the ipsilateral lower pole occurs in approximately 50% of cases, and contralateral reflux occurs in approximately 25%. This complication is likely the result of distortion of the bladder base by the ureterocele. Nonoperative management has also been advocated in cases involving nonobstructed duplex systems with relatively good preservation of renal function, associated multicystic dysplastic moieties, or completely nonfunctioning upper pole moieties. Ureteral reimplantation associated with a ureterocele is more difficult than is uncomplicated reimplantation and is associated with higher failure rates. To increase the chance of success, our recommendation is to create the tunnel for reimplantation above the area of ureterocele excision. This technique allows normal muscle backing for the reimplanted ureter and precludes working in the area of the reconstructed bladder base or marsupialized ureterocele.
7. **d.** Complication rates for robotic-assisted extravesical reimplantation are similar to those of traditional open extravesical reimplantation, such as those for transient urinary retention (0–12%) and contralateral reflux (6–23%). Pelvic plexus visualization has allowed for a nerve-sparing technique that is reported to decrease the rate of postoperative urinary retention and voiding dysfunction following bilateral extravesical robotic-assisted laparoscopic ureteral reimplantation. Complications unique to robotic surgery include potential conversion to an open procedure, longer surgery times, intraperitoneal urine leak, and intraabdominal organ injuries or ileus given the intraperitoneal approach. Advantages may include shorter length of stay and decreased narcotic use compared to open surgery.
8. **e.** Success rates, defined as a lack of VUR on postoperative VCUG, after a single injection are reported to be between 76% and 94%. However, these successes vary based on the experience of the endoscopist, the grade of reflux, the underlying bladder disease, and ureteral anomalies such as duplications and ectopia. In duplicated systems, the success rate after one injection is reported to be approximately 70%.
9. **c.** Late ureteral obstruction is most commonly the result of an error in surgical technique. The most common causes of obstruction are mechanical obstruction and devascularization of the distal ureter. In a child with postoperative obstruction, reoperation should be delayed for ≥3– 6 months to allow the distal ureter to reestablish sufficient vascularity. Robotic/laparoscopic approaches have been shown to have similar success rates to open repair of failed previous antireflux surgery. Percutaneous balloon dilation of ureterovesical junction strictures following reimplantation of the ureter has been described in a limited number of patients with favorable short-term outcomes. Late ureteral obstruction may be associated with abdominal or flank pain, nausea, vomiting, or UTI or it may be completely asymptomatic. Decompression of the upper urinary tract with a temporary percutaneous nephrostomy tube with or without ureteral stenting is recommended in cases of ureteral obstruction. The ability to place a retrograde stent may be limited in the early postoperative period, particularly after a Cohen ureteroneocystostomy. Open retrograde stent placement may rarely become necessary if less invasive percutaneous techniques fail.
10. **e.** The first successful attempt at surgical correction of VUR was reported by Hutch in 1952. Since that time, multiple surgical, endoscopic, and minimally invasive techniques have been described. Open surgical correction

remains the gold standard, with success rates of >98% in most pediatric centers. While surgical results are excellent, most young children with reflux are managed medically, and older children with observation. Additionally, increasing numbers of children are managed with endoscopic techniques. Given multiple treatment options, it remains imperative that the urologist understand the potential risks and complications of each.

CASE 1

1. **a.** Many approaches to correcting vesicoureteral reflux exist: open, robotic, and endoscopic. All may be appropriate in the select patient. Postoperative contralateral reflux has been associated with young age at initial operation, which correlates with a smaller number of cystograms and fewer opportunities to identify contralateral VUR. While some believe it is not warranted, we tend to perform bilateral reimplants in any patient with a history of bilateral VUR even after unilateral spontaneous resolution. Patients with voiding dysfunction often present with wetting, UTI, and VUR. Treatment of the underlying disease with a combination of bladder retraining, treatment of constipation, anticholinergic therapy, and biofeedback frequently eliminates incontinence, UTI, and at times VUR and thus obviates the need for surgical or endoscopic intervention. Normal voiding habits and normal bladder dynamics are essential for successful antireflux surgery.
2. **b.** The most common cause of decreased urine output (<1 mL/kg/hr) after ureteral reimplantation is mild ureteral obstruction resulting from transient edema at the UVJ. Mild dehydration from preoperative fasting and supraphysiologic secretion of antidiuretic hormone in response to surgical stress also contribute to low urine output. This condition generally responds to fluid boluses (10 mL/kg lactated Ringer solution or 0.9% normal saline solution) and resolves 4–6 hours after the surgical procedure with no long-term sequelae. Dehydration may be avoided with vigorous intraoperative hydration (e.g., 40–50 mL/kg during the case) to compensate for fasting and third-space losses. A renal and bladder ultrasound is useful if oliguria persists after volume replacement. Hydroureteronephrosis or urinary extravasation may be evident. These findings may be confirmed with a diuretic renal scan. The ability to place a retrograde stent may be limited in the early postoperative period, particularly after a Cohen ureteroneocystostomy.
3. **e.** The incidence of recurrent cystitis after successful reimplantation has been reported to be up to 39%, and <8% of patients have clinical pyelonephritis. This patient's episodes of pyelonephritis may be due to voiding dysfunction, persistent VUR, or obstruction and should be investigated. Voiding dysfunction may increase the risk of postoperative pyelonephritis after successful reimplantation and should be addressed. The AUA guidelines do not uniformly recommend postoperative VCUG after open surgical repair, but allow the clinical course and family preference to affect the final decision. If a VCUG is obtained, it should be performed 3–4 months postoperatively to allow for resolution of edema or inflammation of the submucosal tunnel. Late ureteral obstruction may be associated with abdominal or flank pain, nausea, vomiting, or UTI, or it may be completely asymptomatic. The diagnosis of obstruction can be made with ultrasound or renal scan.

CASE 2

1. **a.** The AUA guidelines state that (as an option) postoperative cystography may be performed following open ureteral reimplantation and (as a recommendation) that postoperative voiding cystography following endoscopic injection of bulking agents is recommended. There are not yet published recommendations on routine use of postoperative voiding cystourethrogram following robotic correction of reflux.
2. **e.** The use of Dx/HA is contraindicated in patients with dysfunctional voiding as it is associated with persistent VUR. Repeat injection has been reported to have a success rate of 68–89%. Open ureteral reimplantation after failed injection is more difficult than is a primary open reimplantation procedure and may be related to granuloma formation secondary to injection. Salvage open and robotic extravesical approaches to persistent VUR after failed injection therapy have been described with some success.
3. **d.** The use of Dx/HA is contraindicated for patients with Hutch diverticula, active voiding dysfunction, urinary tract infections, nonfunctional kidneys, or ureteroceles.

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59 Complications of Exstrophy and Epispadias Repair

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CHAPTER OUTLINE

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Osteotomy Complications
Bladder Outlet Obstruction
Penile Complications
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Fertility and Pregnancy
Malignant Disease
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KEY POINTS

1. Continence can be achieved in 71–74% of children following the MSRE regimen (exstrophy closure at birth, epispadias repair at 6–12 months, and bladder neck reconstruction as well as an antireflux procedure at 5–6 years). Other repairs (complete primary repair and the Kelly repair) have been offered, long-term outcomes show continence rates of 20%.
2. The success of bladder exstrophy closure depends on the newborn's bladder template size and condition, a tension-free closure, free egress of urine, secure placement of suprapubic tubes and stents, wound care, avoidance of infection, and excellent pain and movement control.
3. The complications of any primary closure include infections, wound dehiscence, bladder prolapse, and urethral outlet obstruction.
4. Diligent care and pampering as well as the liberal use of an indwelling, tunneled epidural catheter, analgesics, antispasmodics, and tranquilizers will provide for a calm, pain-free postoperative course with proper immobilization.
5. Although various anatomic approaches to osteotomy have been implemented, the combined anterior innominate and vertical iliac technique is preferred because of its technical practicality, comparable outcomes, and long-term success.
6. The most common complications of epispadias repair are urethrocutaneous fistulas, urethral strictures, loss of penile skin, and persistent dorsal chordee. However, loss of glans or corpora can occur.
7. Modified Young-Dees-Leadbetter bladder neck reconstruction and ureteral reimplantations (transtrigonal or cephalotrigonal) are performed at 5–6 years of age when the child wants to be dry, will participate in postoperative voiding training, and has a bladder capacity of ≥100 mL and stable urodynamics.
8. Complications of bladder neck reconstruction include difficulty with urinating, persistent incontinence, the development of hydronephrosis due to bladder outlet obstruction, and the formation of calculi.
9. Most patients with failed exstrophy reconstruction require augmentation cystoplasty or continent urinary diversion to provide prolonged stability in the upper urinary tract and continence.
10. Long-term considerations include the appearance of the external genitalia, male fertility, introital difficulties, uterine prolapse, and malignant disease.

The surgical management of classic bladder exstrophy remains a challenge to the pediatric urologist and pediatric surgeon. Multiple reconstructive approaches exist to repair classic bladder exstrophy. The modern staged repair approach to closure of bladder exstrophy (MSRE) has provided excellent long-term successful results.[1–3] This method of treatment consists of bladder, posterior urethral, abdominal wall, and pubic closure in the newborn period, if the newborn is robust with an excellent bladder template. Pelvic osteotomies are performed as needed. Concomitant epispadias repair can be performed in very selected cases, but only by experienced exstrophy surgeons. In most cases, the epispadias repair is performed when the patient is 6–12 months old. This repair precedes bladder neck reconstruction. By adding outlet resistance, epispadias repair facilitates bladder growth to an adequate capacity for bladder neck reconstruction. Along with ureteral reimplantation, bladder neck reconstruction is usually performed at 5–6 years of age when the patient has achieved satisfactory bladder capacity, wants to be dry, and will comply with an intense postoperative voiding regimen. This chapter identifies the complications of all current forms of exstrophy and epispadias treatment and highlights methods to avoid many of these problems.

The modern era of exstrophy reconstruction began in the early 1970s when Jeffs and colleagues[4] and Cendron[5] introduced a staged approach to functional closure of bladder exstrophy. Formerly, this treatment regimen consisted of bladder closure, later bladder neck reconstruction, and finally epispadias repair. However, since the middle to late 1980s with MSRE, reconstructive procedures have evolved and have been altered such that exstrophy closure is performed as a newborn, epispadias repair is performed at 6–12 months of age, and bladder neck reconstruction is undertaken at 5–6 years of age.

The success of the MSRE approach has been quite encouraging. In specialist centers, continence is achieved in 71–74% of children.[6–8] In a series of 67 patients treated at the Johns Hopkins Hospital in Baltimore by a single surgeon and followed up for ≥5 years, 70% achieved continence (daytime and nighttime) and 80% achieved social continence (dry for ≥3-hour intervals).[6] Additionally, we have had excellent success with MSRE done outside of our institution with referral for continence procedure. Eighty-three percent (57 of 68) of patients referred were continent via urethra without a need for augmentation or for clean intermittent catheterization (CIC).[9]

This review of complications associated with classic bladder exstrophy and epispadias includes the experience of 213 patients who have been seen and treated at the Johns Hopkins Hospital between 1988 and 2004 by Gearhart and colleagues.[6] These patients, as well as those referred either for exstrophy complications or after initial closure for epispadias repair or bladder neck reconstruction, form the substance of this chapter.

To achieve a successful treatment result by way of functional closure, the needs of each child with bladder exstrophy must be carefully considered at birth. Numerous factors determine the surgical success of bladder exstrophy closure, including the newborn's bladder template size and condition, tension-free closure, free egress of urine, secure placement of suprapubic tubes and stents, wound care, avoidance of infection, movement, and prevention of raised intraabdominal pressure that occurs with straining, coughing, and postoperative ileus.[10–12]

Bladder size and functional capacity of the detrusor muscle are important factors in the ultimate outcome of closure. It is imperative not to confuse apparent bladder size with potential bladder capacity; true bladder size can be accurately assessed only while the patient is under anesthesia. Although the bladder may appear small on preliminary examination, an examination while the patient is under anesthesia may reveal a bladder with suitable capacity that indents easily when it is depressed by a gloved finger.

If the initial bladder capacity after successful closure is estimated to be ≥5 mL, one can expect the bladder to develop adequate size and capacity over time. However, repeated irritation or trauma not only produces a bladder that is unsuitable for closure, but also hinders subsequent bladder growth. In addition, a small fibrotic bladder patch without elasticity or contractility may not be appropriate for primary closure. Other conditions that prevent successful primary closure include ectopic bowel, severe upper tract changes, and significant hamartomatous polyps.

In some neonates with small bladder templates, it may be prudent to wait until the child is 4 to 6 months of age, to allow the child and the bladder to grow, and then undertake closure with epispadias repair under testosterone stimulation, rather than risk a failed closure in the newborn period.[13] Conversely, many patients with small bladders do undergo closure, and some obtain a volume that can yield a satisfactory dry interval after bladder neck reconstruction. In addition, a small bladder that is successfully closed can be subsequently used as a template for ureteral reimplantation and bladder augmentation if adequate bladder capacity is not eventually attained.

The main complications of primary bladder exstrophy closure are complete wound dehiscence (Fig. 59.1), bladder prolapse (Fig. 59.2), and urethral outlet obstruction (Fig. 59.3). Other resultant complications of bladder closure include bladder and renal calculi. In some repairs, such as the complete primary repair of exstrophy (CPRE), glans and corpora loss has been reported. In addition, vesicocutaneous fistula has also been reported by Massanyi et al.[14] This often is a subtle sign of a failed closure as the pubis is often separated and the bladder assumes a very superficial position where it is easy for fistulization to occur. This occurrence must be carefully evaluated as reclosure is oftentimes required.[14] With the modern treatment of bladder exstrophy, the incidence of all the aforementioned complications has declined significantly. These complications and methods to avoid them are discussed in the following sections on initial bladder closure, epispadias repair, bladder neck reconstruction, and long-term considerations.

Initial Bladder Closure

OVERVIEW

The technique for primary bladder closure that has been previously described and diagrammed is to close the bladder template, bladder neck, and proximal posterior urethra well up onto the shaft of the penis in a secure manner

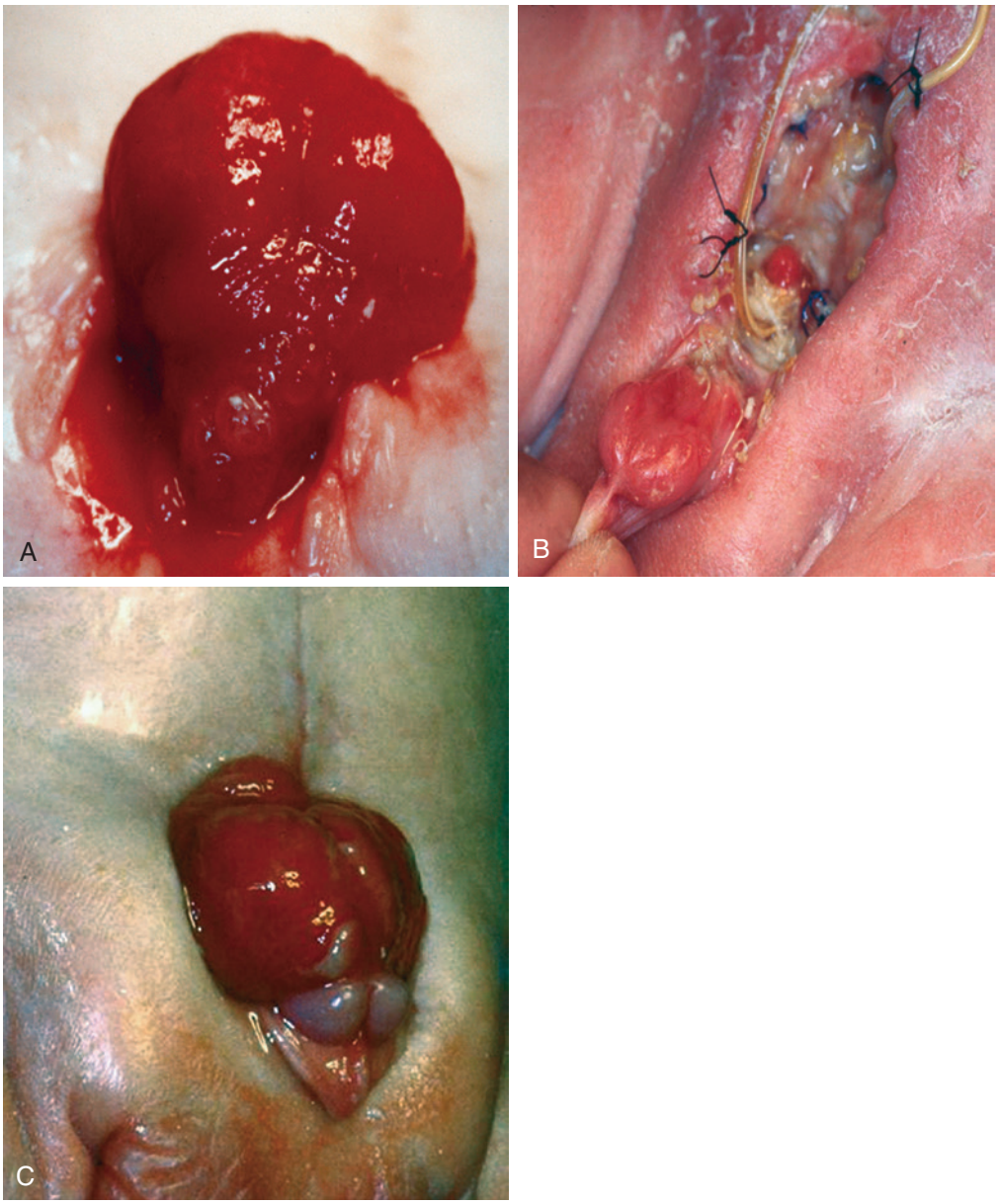


Figure 59.1 A, Complete bladder dehiscence in a 2-month-old girl whose primary exstrophy closure was performed at 2 days without osteotomy. B, Bladder dehiscence with early granulation tissue following initial exstrophy closure with insufficient mobilization of the vesicourethral unit. C, Bladder dehiscence from the lower end of the midline abdominal incision in a boy with loss of penile skin.

to allow free egress of urine.[1] In very selected cases, this technique can be combined with formal epispadias repair in patients who have a generous bladder template, an adequately sized penis, and a deep urethral groove. However, this complex procedure should only be performed by surgeons experienced in treating bladder exstrophy. Regardless of the chosen method, free egress of urine during healing is essential.

To prepare the newborn infant for later bladder neck repair in an attempt to achieve continence, the bladder, bladder neck, and posterior urethra must be placed well within the pelvis. This placement allows the bladder to drain under a well-closed pubic arch and for the pelvic floor musculature to aid in eventual continence by compressing the urethra to interrupt the urinary stream. In addition, ultimate tailoring of the bladder neck in a "funnel" manner and suspension of the vesicourethral angle are more readily accomplished when the bladder and bladder neck are located deep in the pelvis. These later maneuvers are distinctly more difficult when the bladder is superficial and is covered merely by skin or attenuated fascia and when continued mobility of tissue between the pubic bones exists.

The distance from the anal verge to the umbilicus is significantly shortened in exstrophy. Therefore deeper structures are crowded into a smaller space. Positioning these structures into the deep pelvis can be accomplished only by radical mobilization of the urogenital diaphragm and medial aspects of the pubic bone down to the level of the levator hiatus. This maneuver allows the posterior urethra and bladder to be placed deeper into the pelvis and to exit

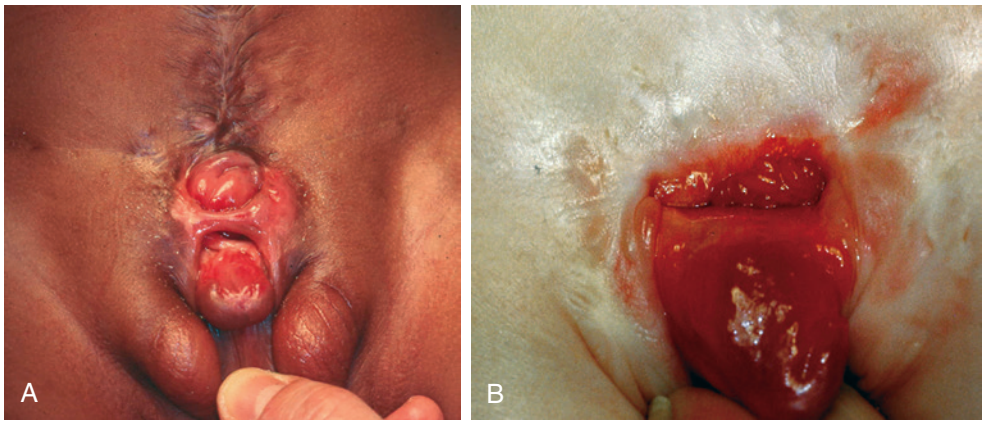
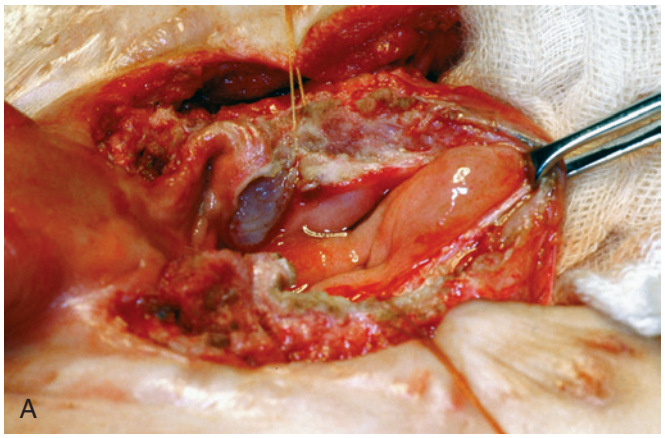


Figure 59.2 A, Bladder prolapse seen in a 2-year-old female after adoption. Note the prominence of the cystoscopic light source through the skin consistent with fascial dehiscence. B, Minor bladder prolapse that developed within 3 months in a 16-month-old boy who underwent exstrophy closure at 3 days without osteotomy. Reclosure was performed with epispadias repair and osteotomy at 18 months.



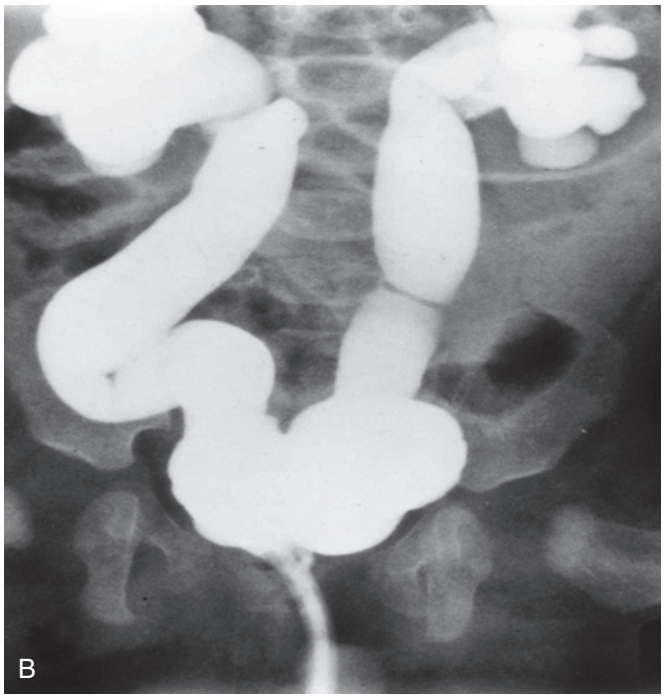


Figure 59.3 A, Dense urethral stricture following initial exstrophy closure using paraexstrophy skin flaps with a thickened bladder and posterior urethra. B, Resultant bladder and upper urinary tract decompensation.

the pelvis more posteriorly. At the same time, sectioning of the suspensory ligament and anterior attachments of the penis helps correct dorsal chordee and allows the penis to gain length and to lie in a more dependent position.

Formerly, paraexstrophy skin flaps were used to lengthen the urethra and to allow the bladder neck to recede into the pelvis. However, with the modern techniques of epispadias repair, including modified Cantwell–Ransley repair, this procedure is performed only rarely. In our practice, paraexstrophy skin flaps are only used if the verumontanum is located distal on the shaft of the penis near the glans; in this situation, the foreshortened urethral plate makes placing the posterior urethra and bladder deep into the pelvis impossible. These flaps are constructed with great care and are monitored carefully for the first several months after closure.

COMPLICATIONS

The previously discussed bladder and posterior urethra closure is easily accomplished when it is performed with a sterile field and with tissues that could be brought into apposition without tension and immobilized during the healing period. Infection, tension, and movement, along with an indwelling urethral catheter, can cause wound separation and exposure of deeper holding sutures that can result in subsequent minor or major degrees of bladder prolapse or even complete dehiscence.

Infection

To limit the potential for infection, the bladder should be closed as soon after birth as possible. From birth until the time of bladder closure, the bladder should be protected with a nonadherent plastic film such as plastic (Saran) wrap to prevent petroleum jelly, gauze, umbilical clamps, or the diaper itself from denuding the mucosa and removing the epithelium and natural surface antibodies. The bladder surface should be irrigated at each diaper change with sterile saline solution at body temperature. All efforts should be made to minimize diaper rash and ammonia burns that occur in this area from contamination with urea-splitting organisms. The umbilical stump should be tied with a silk suture below the umbilical clamp and the clamp removed to protect the bladder template.

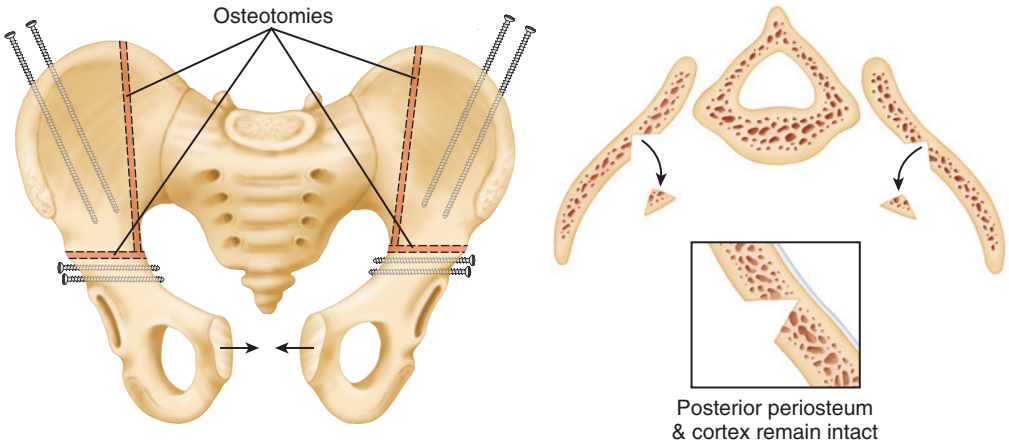


Figure 59.4 Combined anterior innominate and vertical iliac osteotomy and pin placement with preservation of posterior periosteum and cortex.

At the time of initial closure, antibiotics (typically ampicillin and gentamicin) are given preoperatively and are continued for 10 to 14 days postoperatively, with subsequent transition to oral prophylactic antibiotics. Antibiotics remain an essential adjunct to successful bladder closure because exstrophic bladders and the surrounding tissues inevitably become contaminated. The administration of antibiotic therapy is an attempt to convert the contaminated area into a clean surgical wound. In addition, the local area is thoroughly washed and cleansed with povidone-iodine, and the bladder and its interstices are liberally soaked.

The patient is prepared from the nipples to the knees anteriorly and from the base of the scapula down to the popliteal fossa posteriorly. The entire area is then draped into the operative field. This method allows access to the posterior body while manipulating the pelvic ring to bring the pubic bones together and to the orthopedic fixating device should an osteotomy be performed. Finally, gauze or an adhesive surgical dressing is inserted into the patient's anus to prevent stool contamination during the procedure.

Wound Tension and Mobility

Wound tension and mobility also contribute to wound dehiscence. These situations are prevented by firm anterior fixation of both sides of the pubis, whether or not an osteotomy is performed. After the induction of anesthesia, the patient is examined to reapproximate the pubic diastasis, and the elasticity of the pubis is noted. As long as the pubic bones can be easily coapted without tension, closure is performed without osteotomy. This situation typically occurs when the pubic diastasis is ≤4 cm, and particularly when the newborn undergoes the closure procedure in ≤72 hours. If the diastasis is >4 cm or if any uncertainty exists about the mobility of the pubic bones, an osteotomy is warranted. Those patients with a very large bladder template and a wide pubic diastasis stand to benefit the most from successful closure, and a bilateral osteotomy will help protect the closure and ensure an excellent result. Osteotomy reduces tension on the midline wound closure and is most beneficial in those patients who do not undergo delayed closure, reclosure after initial failure, or those newborns with a large size bladder template with wide diastasis.

Our experience with combined anterior innominate and vertical iliac osteotomy in >100 patients led us to adopt this procedure because of decreased blood loss and operating time (Fig. 59.4).[15] When the operation is performed using this position, the anterior apposition is achieved without flattening the pelvis and thus without drawing the penis inferiorly under the pubic closure. Therefore penile length is enhanced rather than decreased by the osteotomy procedure.

Movement during healing often results in excessive moisture, eventual infection, and subsequent dehiscence. Fixation of the wound is vital for initial healing. A three-part plan is recommended to obviate the problem:

1. An attempt is made to coapt the pubic bones with a horizontal mattress suture tied on the outside of the closure. When this is accomplished, another heavy suture can be easily placed in the lower rectus fascia at the junction of the rectus fascia onto the top of the pubic bone, which is now closer to the midline. The pubic stitch must be of very large caliber, usually number 2 nylon, to give the initial strength required for closure. The same caliber suture is also used in an interrupted fashion above the pubic closure in the lower rectus fascia. As shown by biomechanical testing by Sussman and associates,[16] number 2 nylon suture provides the best load-to-failure ratio among several methods of pubic approximation using various commonly employed suture materials. However, all approaches are weak compared with the intact pelvis.
2. Patients who undergo a closure procedure without pelvic osteotomy are kept in modified Bryant's traction for 4 weeks to complete pelvic ring closure and pubic healing. Patients who undergo combined anterior innominate and vertical iliac osteotomies are kept in an external fixating device and modified Buck's traction for 4 weeks in primary closures and 6 weeks in secondary closures (Fig. 59.5). Plaster casting, mummy wrapping, and other maneuvers have been used by other surgeons but are not recommended because these methods are less effective and are associated with significant complications (Fig. 59.6).[10,17] In a series of 86 failed closures in patients referred to the Johns Hopkins Hospital for definitive treatment, these alternative measures were associated with failure of the closure in a majority of cases because they provided insufficient immobilization.[17]

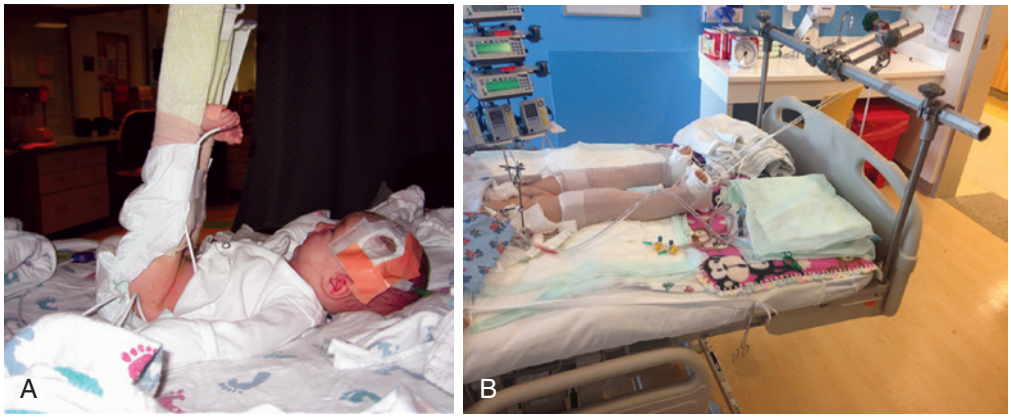


Figure 59.5 Adequate postoperative pelvic and lower extremity immobilization. A, No osteotomy: modified Bryant's traction for 4 weeks. B, With osteotomy: Buck's traction and external fixator for 4 weeks (6 weeks in secondary closures).

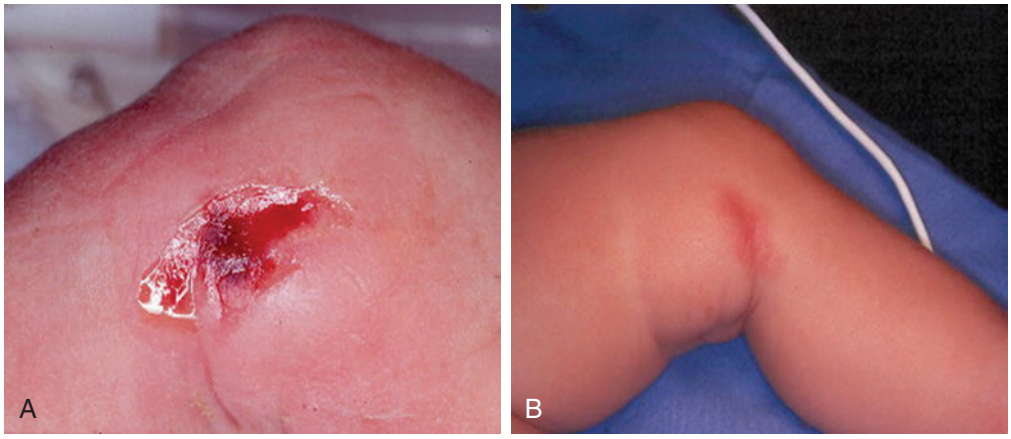


Figure 59.6 Complications of mummy wrap. A, Pressure sore on the medial knee after wrap removal. B, Persistent scar after 3 months.

3. The child's muscular activity, incisional pain, and bladder spasms must be controlled to permit wound fixation. In our unit these goals are achieved through collaboration with our pediatric anesthesia colleagues who place a tunneled epidural catheter, which is left indwelling after closure. This epidural catheter, along with supplemental intravenous narcotics, diazepam, and anticholinergics, keeps the child still and obviates pain. This treatment necessitates a team approach with physicians, nurses, parents, and members of the pediatric pain service who pamper the child to ensure that pain, frustration, hunger, and muscle and bladder spasms do not produce undue or prolonged activity that defeats attempts to prevent wound mobility.

Mothers are encouraged to nurse and cuddle their babies while these infants are in traction and to assist the nursing staff when the children appear agitated. When the mother is not present during the postoperative healing phase, recorded tapes of fetal heart sounds are often used to simulate the intrauterine environment. Through diligent care and pampering as well as the liberal use of the continuous caudal epidural catheters, analgesics, antispasmodics, and tranquilizers, the goal of providing a calm, pain-free postoperative course with proper immobilization may be reached.

Osteotomy Complications

We believe in performing pelvic osteotomies as indicated because 90% of children referred to our institution following partial or complete bladder dehiscence do not have an osteotomy or adequate lower extremity immobilization.[17,18] Controlled fracture of the pelvis allows the pubic rami to be approximated in the midline and thereby permits the bladder to be placed in a more physiologic position. Although various anatomic approaches to osteotomy have been implemented, we favor the combined anterior innominate and vertical iliac technique because of its technical practicality and equivalent or improved outcomes.[19,20]

In a series reported by Baird et al.[15] of 68 patients who underwent combined anterior innominate and vertical iliac osteotomies, no episodes of osteomyelitis and only one external fixator pin site infection occurred. The complete absence of osteomyelitis in this modern series is probably the result of the use of broad-spectrum antibiotic coverage as well as the meticulous pin site care given by the nursing staff at our institution. With careful attention to wound care, even superficial pin site infections are rare.

Another complication of the osteotomy procedure described in some older series is partial femoral nerve palsy.[19] We have since changed our practice such that currently, after fixator placement, we do not tighten the device until

≥7 days after the primary surgical procedure. The external fixating device is then rotated medially to help ensure complete pubic bone apposition. With this modification, we have observed only two partial femoral nerve palsies in our last 100 patients, and both completely resolved.[15]

Undue blood loss has not been a problem with pelvic osteotomy, even in very young patients. Nevertheless, osteotomy wounds do ooze fairly frequently until clot formation inside the osteotomy is adequate. In some patients who have undergone failed closure and who need repeat pelvic osteotomy, blood loss can be more extensive and some patients may require transfusion. Nonetheless, the added benefit of closure performed with repeat pelvic osteotomy is worth the slight increase in operative blood loss.[20]

The return of pubic diastasis occurs in all patients, especially in young infants in whom the pelvic bones are not as strong. However, the diastasis is less than the initial defect, and when patients undergo bladder neck reconstruction, the residual diastasis is narrow and a firm intrasymphyseal bar is easily palpated. This observation underscores the importance of adequate fixation and solid closure of the pubis to allow a strong intrasymphyseal bar to form. Although it is not sufficient to prevent ultimate recurrence of some degree of pubic diastasis, this union is essential during the immediate postoperative period of wound closure and healing. This point was aptly demonstrated in the report by Baird et al.[15] who noted that none of the patients with classic bladder exstrophy who underwent a combined osteotomy developed bladder prolapse or wound dehiscence.

Bladder Outlet Obstruction

When paraexstrophy skin flaps are used, urethral stricture can occur where the flaps join in the midline or to the bladder neck. These strictures have generally been treated successfully with dilation alone and only a few have required operative revision. However, several patients referred to our institution developed severe stricture at this location that resulted in massive hydronephrosis and reflux; these patients generally required multiple procedures to correct this problem.

In a review by Gearhart and associates,[21] 31 of 78 patients (40%) who had undergone paraexstrophy skin flap procedures with initial bladder exstrophy closure developed strictures. Various maneuvers were employed to correct these problems including direct vision urethrotomy in 12 cases, urethral dilation in four cases, open revision in three cases, and full-thickness grafts in five cases. The other seven patients had such complex strictures that they required continent diversion (five), colon diversion (one), or cutaneous ureterostomy (one). The last two patients had undergone vesicostomy for their strictures elsewhere before they were referred to our institution.

Despite the decreased use of paraexstrophy skin flaps, they are a viable approach when the urethral plate is very short. This will allow positioning of the bladder in the deep pelvis behind the pubic closure by lengthening the urethral plate. The use of paraexstrophy skin flaps demands special attention to design, careful placement, and avoidance of urinary drainage catheters through the urethra. Indwelling catheters through the urethra can cause ischemia leading to the aforementioned complications. When paraexstrophy skin flaps are used, careful follow-up, especially in the immediate 4–6 postoperative months, is mandatory to avoid complicating strictures and their sequelae.

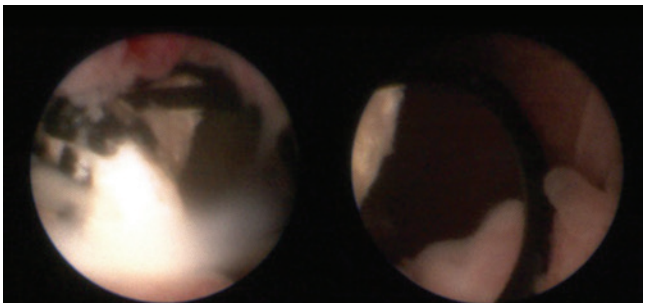


Figure 59.7 Erosion of the intrapubic stitch seen with two views cystoscopically prior to epispadias repair with associated stone.

We have also seen severe urethral strictures after CPRE, as described by Grady and Mitchell,[22,23] and after the Kelly repair[24] using radical soft tissue mobilization.[23,24] In many of the patients undergoing these repairs, urethral closures associated with stricture formation occurred. Whether these complications resulted from ischemic damage of the urethral plate or technical error is unclear. However, severe strictures can be seen after both the CPRE repair and the Kelly repair.[25,26]

Another outlet complication of primary closure is erosion of the intrapubic stitch into the posterior urethra during the healing process (Fig. 59.7). This complication can manifest as urinary tract infection a few months after primary closure, increasingly dry diapers in the 2 or 3 months after closure, or high residual urine volumes in the postoperative state after healing has occurred but before removal of the suprapubic tube. Immediate cystoscopy should be performed to rule out any form of obstruction if hydronephrosis is seen on a postoperative ultrasound scan, if a urinary tract infection occurs, if high residuals arise after healing is completed, or if diapers seem dryer.

An intrapubic stitch that has eroded into the posterior urethra >4 months after the operation can easily be removed through a small suprapubic incision. When this complication occurs in the immediate postoperative state, we typically leave the suprapubic tube in place for 2–3 months and then remove the stitch through a small suprapubic incision. Although this complication is rare, it led us to use AlloDerm (collagen matrix) as an extra level of soft tissue between the intrapubic stitch and the posterior urethra routinely with our exstrophy closures. With this modification, no stitch erosions into the posterior urethra have occurred; however, we have seen one erosion of an intrapubic metal bar in the posterior urethra after reclosure with osteotomy, which was successfully treated with debridement, multiple tissue layer interpositon, and wound vacuum placement.

Penile Complications

Most penile complications have been seen in CPRE and the Kelly radical soft tissue mobilization procedure. Loss of the glans, loss of one or both corpora, and loss of the entire urethral plate have been reported (Fig. 59.8).[25–27] In a recently reported series, of 55 males referred for treatment after CPRE, 13 patients had major penile soft tissue loss.[28] Whether these disastrous complications are the result of damage to the terminal arteries of the penis or injury to the

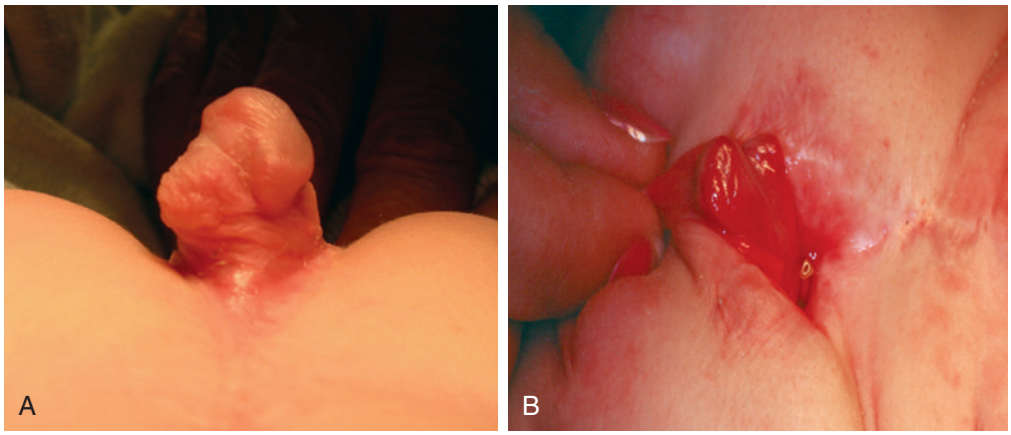


Figure 59.8 A, Loss of left hemiglans following complete primary repair of exstrophy. B, Loss of right hemiglans and distal corpora.

bulbar artery as it exits into the corpus spongiosum from the common penile artery is unclear. In addition, excess venous congestion of these tissues from overzealous pubic closure could be implicated. If congestion occurs after pubic closure, the intrapubic stitch should be removed and replaced more cephalad on the pubic rami. Whatever the cause, this operation carries significant risks and should be performed only by experienced surgeons.

Other Complications

Penile lengthening procedures must not be taken lightly because brisk bleeding can occur during mobilization of the prostatic plate in the male patient and can lead to damage to the corpus cavernosa or spongiosum. Care must be taken during dissection over the corporal bodies, especially between the lower edge of the urogenital diaphragm and the urethral plate on top of the corpora cavernosa. In some referred patients, corporal damage was so severe that it resulted in the inability to achieve erection in the corpus on one side. If this condition is not corrected, it will permanently interfere with erections and sexual function.

Hypertension remains a major concern in patients undergoing primary closure. This problem can be eliminated by ureteral intubation begun at the time of closure and maintained for 10–14 days postoperatively. Bladder drainage is accomplished with a suprapubic Malecot catheter. However, if the ureteral tubes are draining well and the child will be in traction for 4–6 weeks, we frequently do not remove the stents until healing is complete.

A commonly seen complication of ureteral intubation is blockage of the small ureteral stents. Normally, these stents are 3.5 to 5Fr pediatric feeding tubes that have a small perforation at the end. These tubes are easily clogged by debris or small blood clots, and we simply incise the end of the tube to make one large hole that is easier for irrigation. These stents are secured to the suprapubic tube at the skin line with Steri-Strips to keep them in position and to prevent inadvertent removal. The stents and the suprapubic tube are irrigated at regular intervals to insure patency.

LATE POSTOPERATIVE STATE

To prevent complications after the period of immobilization, external fixation, and healing, the adequacy of the bladder outlet should be tested before discharge. After the ureteral stents are removed, a renal ultrasound is obtained to rule out hydronephrosis. The suprapubic tube is then clamped and residual urine volumes are measured over a few days via gravity drainage. If the residual urine volumes are consistently low, the suprapubic tube is removed. A sample for urine culture is always sent from the bladder through the suprapubic tube before its removal to ensure that the bladder urine is sterile. If the residual urine volumes are high, cystoscopy is mandated to look for a stricture or erosion of the intrapubic stitch into the posterior urethra.

Patients are administered long-term suppressive antibiotics postoperatively, and the effectiveness of these drugs is monitored by monthly urine cultures. Renal and bladder ultrasounds are obtained 6 weeks after discharge and again at 4 months. This monitoring ensures that the upper urinary tract drains appropriately and that obstruction or reflux is not causing any undue change in the upper urinary tract.

Treatment of the newborn with bladder exstrophy is a significant undertaking that requires a high-quality team of neonatologists, pediatricians, pediatric anesthesiologists, nurses, pediatric orthopedists, and surgeons. To protect against and manage complications, a concentrated team effort should be organized so that the child can be adequately prepared for a formal continence procedure at a later date.

INCONTINENT INTERVAL

Although patients who underwent successful newborn exstrophy closure may appear free of obvious complications, detailed follow-up is required for early detection of impending problems. Normal bladder closure converts a child with exstrophy into one with complete epispadias and incontinence. When epispadias repair is combined with bladder closure in the newborn period, the child remains incontinent and follow-up is the same. Ultrasound scans are repeated at regular intervals during the 2–3 years after closure to detect any upper urinary tract changes that can result from obstruction, reflux, or infection. Children who develop a significant dry interval early on must be carefully monitored for outlet obstruction.

CONCLUSION

The ability of functional closure of bladder exstrophy to yield a 70–80% continence rate with preservation of renal

function was documented by several series.[3,6–8,12,29] However, the success of initial bladder closure most significantly affects the eventual ability to achieve continence through spontaneous voiding without the use of clean intermittent catheterization. After one failed bladder exstrophy closure, the chance of achieving adequate capacity for bladder neck reconstruction is reduced to 68%,[30] and the chance of attaining ultimate dryness after bladder neck reconstruction is only 30%.[31] After two failed exstrophy closures, only 40% of patients achieve enough bladder capacity for bladder neck reconstruction and only 20% overall achieve continence; 80% of these patients require intermittent catheterization and bladder augmentation.[10] Thus, after two or more failed exstrophy closures, only 20% of patients are continent and voiding through the urethra. This underscores the need for successful primary closure and illustrates the need for closure to be performed at specialized centers of excellence.

Epispadias Repair

OVERVIEW

Many surgical techniques have been described for reconstruction of the penis and urethra in patients with classic bladder exstrophy. Four key concerns must be addressed to ensure a functional and cosmetically acceptable penis:

1. Dorsal chordee
2. Urethral reconstruction
3. Glandular reconstruction
4. Penile skin closure.

Historically, most epispadias repairs borrow heavily from Cantwell's original description in 1895.[28] Although these early pioneering steps in penile reconstruction were used, devascularization of the urethral closure occurred and led to the abandonment of this approach. Young modified Cantwell's technique by leaving the urethral plate attached to one corpus and transposing this plate ventrally.[32]

Although some penile lengthening can be achieved with release of chordee during the initial bladder closure, it is often necessary to perform penile elongation with release of chordee at the time of epispadias repair in patients with bladder exstrophy. All remnants of the suspensory ligaments and residual scar tissue must be excised, and further dissection of the corpus cavernosa from the inferior pubic ramus is often required. Lengthening of the urethral groove is also essential. Regardless of whether paraexstrophy skin flaps were used at the time of bladder closure, further lengthening is needed. The urethral plate must be completely dissected from the corporal bodies both proximally to the bladder and distally toward the glans to achieve maximal penile length. However, the urethral plate is left attached to the distal centimeter of the glans and the Ransley mesentary to preserve blood supply.

Furthermore, to release dorsal chordee, one can lengthen the dorsomedial aspect of the corpora by incision and anastomosis of the corpora and by placement of dermal graft to allow lengthening of the distal aspect of the corpora. Ransley and colleagues[33] introduced this concept of releasing dorsal chordee by incision and anastomosis of the dorsomedial aspect of the corpora over the urethra and ventral meatotomy at the distal end of the glans and thus moving the urethra to a more anatomic position. Various authors have reported success with the Cantwell–Ransley repair and modifications thereof.[34–38]

Urethral reconstruction is an important aspect of external genital reconstruction in patients with bladder exstrophy. This procedure can be accomplished by several methods. In the late 1980s, we began to use the Cantwell–Ransley repair exclusively for the repair of epispadias in patients with bladder exstrophy or epispadias. We reported on our success with long-term experience with this procedure.[34] In our variation of the Cantwell–Ransley repair, the urethral plate is mobilized almost completely from the glans penis to a location above the prostate and is transferred to the ventrum of the penis under the separated corpora. Mitchell and Bagli[39] reported a technique of complete disassembly of the corpora from the urethral plate in an attempt to lengthen the penis and to correct dorsal chordee. Unfortunately, 30–70% of these patients are left with hypospadiac meatus requiring hypospadias repair.[39–41]

Historically, bladder neck reconstruction was performed before urethral or penile reconstruction. However, the finding of a significant increase in bladder capacity after epispadias repair in those patients with small bladder capacity prompted a change in our management program in the late 1980s. In a review of patients with small bladders after initial closure that were deemed inadequate for satisfactory bladder neck repair, we noted a mean increase of 55 mL after only 22 months following urethroplasty for epispadias.[42] These patients subsequently underwent successful bladder neck reconstruction. At present, construction of a neourethra, penile lengthening, and dorsal chordee release are performed between 6 and 10 months of age. Because most boys with bladder exstrophy have a small, widened penis and a shortage of available skin, all our patients undergo testosterone stimulation before urethroplasty and penile reconstruction.

COMPLICATIONS

The most common complication of epispadias repair is a urethrocutaneous fistula. In a series of 129 Cantwell–Ransley repairs by Baird et al. of the Johns Hopkins Hospital,[34] fistulas developed in the immediate postoperative period in 16% of patients with bladder exstrophy and in 13% of patients with complete epispadias. In 5 of 18 patients, the fistulas closed spontaneously in the first few postoperative months. The other 13 patients underwent a separate procedure to close the fistulas.

Fistulas in this group of patients all uniformly appeared at the base of the penis, where the urethra comes up proximally between the corporal bodies and then goes under the pubic bone. Initially, we thought that this location would be the most common area of fistula formation when paraexstrophy skin flaps were used. However, fistulas occurred more often in patients with an intact urethral plate. In all patients, whether paraexstrophy skin flaps were used or not, fistulas occurred at the base of the penis. Currently, while performing epispadias repair, we harvest and de-epithelialize the inner aspect of the ventral foreskin or use the tunica vaginalis as a soft tissue flap to cover the urethral repair at the base of the corporal bodies before it dives under the

corpora to the level of the prostate. Our hope is that adding this extra layer of soft tissue will further reduce the incidence of fistula.

Although the most common complication of epispadias repair is urethrocutaneous fistula, in a series of 129 Cantwell–Ransley repairs, nine cases of urethral stricture occurred, all at the proximal anastomosis.[34] One of these strictures responded quite well to direct vision internal urethrotomy. Other techniques included urethral dilation and intermittent catheterization, free full-thickness skin grafts, and buccal grafts. Currently, we use a buccal mucosa graft to replace the urethra instead of a full-thickness skin graft; therefore the incidence of stricture formation should decrease in time.

Another complication of epispadias repair is loss of penile skin. As mentioned previously, these patients have a preexisting paucity of skin, and testosterone is used to increase the vascularity and availability of local penile skin. In the previously mentioned series by Baird et al.,[34] 15 patients had minimal separation of dorsal skin that granulated without incidence. No instances of substantial skin or glans loss have been observed in our entire experience with the Cantwell–Ransley repair.

Another epispadias repair procedure is complete penile disassembly, as described by Mitchell and Bagli in 1996.[39] The fistula rate reported with this repair was 18% in a small published series.[43] Some of the most worrisome complications of epispadias repair have been observed with this approach. Loss of the glans, loss of the corpora, and loss of the urethral plate were reported in a combined series by Husmann and Gearhart.[27] In addition, data by Purves and Gearhart showed similar risks with the Kelly radical soft tissue mobilization technique.[26] These serious complications point to the risks of this procedure, especially when it is performed by a surgeon who does not routinely operate on delicate, infant tissues, because they can doom the ability of the child to undergo later bladder neck repair and further reconstruction.

Dorsal chordee can persist after epispadias repair. In the review of 129 patients with the Cantwell–Ransley repair, most patients had penises that were straight or deflected downward, but many of these patients were still quite young.[34] Patients >18 years old who engage in satisfactory sexual intercourse state that their penises are quite acceptable, both functionally and cosmetically. Whether simple rotation of the corpora is adequate or whether corporal incision and anastomosis are required is a judgment call at the time of the surgical procedure. Whether these patients require further penile straightening as they achieve sexual maturity is unknown, but they certainly will require prolonged follow-up.

Our experience with older children finds that mobilization of the urethral plate and corporal rotation are inadequate to correct the chordee completely. Incision and anastomosis of the corporal bodies or dermal grafts are required to achieve penile straightness in these older patients. With current methods of epispadias repair, the urethra is straight under the corporal bodies. The urethra obtains a more anatomic and straighter course and is supported dorsally by the more normally placed corporal bodies. This issue has become increasingly important because, should intermittent catheterization be needed in the future, an easily catheterized urethra may obviate the need for a continent urinary stoma. More than 100 patients have undergone cystourethroscopy or urethral catheterization and a smooth urethral tube that is easy to negotiate was present in all patients.

Bladder Neck Reconstruction

OVERVIEW

Bladder neck reconstruction is usually performed at the age of 4–5 years when the child is mature enough to want to be dry and participate in a postoperative voiding training program. Bladder capacity is measured with a gravity cystogram obtained while the child is under anesthesia. If the bladder capacity is ≥85 mL, bladder neck reconstruction can be considered.[10] Because all patients with bladder exstrophy have vesicoureteral reflux, an antireflux procedure is required at the time of bladder neck repair. One common problem that we have seen in multiple patients is bladder neck reconstruction performed when the child is 2–3 years of age. At that time, the child has no interest or need to be continent and these operations are doomed to failure.

Some repairs such as the CPRE and the Kelly repair have been purported to decrease the number of operations and to obviate the need for bladder neck reconstruction. In a series by Grady and associates,[44] 72% of female patients and 86% of male patients who underwent CPRE required bladder neck reconstruction, as did 80% of patients in another series by Borer and colleagues.[45] Recent series have shown that the vast majority of patients will require bladder neck reconstruction after CPRE.[46,47]

At the time of initial bladder neck repair, an attempt is made to obtain continence by creating a long, narrow bladder neck and an elongated posterior urethra in the modified Young-Dees-Leadbetter manner.[48] The reflux is corrected by transtrigonal or cephalotrigonal reimplants, which are also necessary to move the ureters away from the bladder neck repair so that trigonal tissue can be used to create the bladder neck. In the past, the classic Cohen transtrigonal procedure was used exclusively.[49] However, when the ureters lie low and laterally on the bladder floor, our preference is a more cephalic course for the ureters that involves using the same hiatus but constructing a submucosal tunnel in the cephalad position.[50] This procedure brings the ureteral meatus from each ureter together near the midline of the bladder. This approach works quite well with ureters positioned onto the upper aspect of the trigone and away from the newly reconstructed bladder neck.

Outlet pressure and continence length can be measured by intraoperative urethral pressure profilometry, and resistance of the bladder neck is measured after bladder closure. Our research indicates that urethral closure pressure of 70 to 100 cm H_2O over a length of 2.5 cm is necessary to achieve a successful outcome.[51] Finally, a Marshall-Marchetti-Krantz bladder neck suspension is performed to further increase the continence and urethral closure pressure further.[52] This repair must be allowed to heal for 3 weeks without indwelling urethral stents and with a suprapubic tube to drain the urine before voiding trials begin.

Numerous factors account for a successful outcome after bladder neck repair. Leadbetter[48] considered the length of

the bladder neck to be the most significant factor contributing to continence. Therefore, we follow his recommendation and construct the bladder neck approximately 2.5–3 cm in length.[48] In addition, bilateral pelvic osteotomies performed at the time of initial closure permit placement of the urethra in the pelvic ring. This maneuver allows for the levator ani and puborectalis muscles to aid in voluntary urinary control. A bladder neck suspension aids in preventing static and stress incontinence. The effectiveness of bladder neck suspension has been demonstrated intraoperatively using urethral pressure profilometry.[51]

The mechanism for achieving urinary continence must not compromise renal function. Both intravenous pyelography and ultrasound studies have been used to evaluate the upper urinary tract in our patients following bladder neck reconstruction. In a series of 189 patients treated by a single surgeon at our institution from primary closure through bladder neck reconstruction, 67 male patients were identified who had a minimum of 5-year follow-up. Of these, only one patient developed hydronephrosis after bladder neck reconstruction, and that complication was corrected with reoperative surgical repair.[6] All of our patients and parents undergo an intensive voiding improvement program prior to bladder neck reconstruction including not only the urologist, but also senior clinical nurses and child psychologists to ensure patient readiness.

COMPLICATIONS

Complications of bladder neck reconstruction do occur and include the following:

1. Difficulty with urinating after bladder neck repair
2. Persistent incontinence
3. Development of hydronephrosis.

In the previously mentioned series of 67 bladder neck reconstructions with long-term follow-up, difficulty with urination developed in 20% of patients postoperatively.[6] All these patients learned to void except a single patient, who required long-term intermittent catheterization for continence.

Obstruction to the flow of urine occurring at the end of the 3-week healing period may be managed by continued suprapubic drainage, gentle dilation of the urethra with passage of an indwelling urethral catheter, or intermittent self-catheterization. As an initial step, an 8Fr Foley catheter is placed while the patient is under anesthesia; the surgeon uses a pediatric cystoscope and guidewire during catheterization, and the catheter is left in place for 3–5 days. After removal of the catheter, voiding usually occurs. If difficulty persists, an extended period of catheter drainage is employed before another voiding trial is attempted.

As indicated from the results of our study, urinary continence with a long-term dry interval does not occur immediately after bladder neck reconstruction and can take ≤2 years to achieve. In our series, the interval between bladder neck reconstruction and urinary continence ranged between 4 and 23 months, with a mean time of 14 months.[6] Nighttime dryness varies but can also take ≤2 years to obtain. Most patients have dry intervals of 3 hours within the first year. During the second year, a few additional patients achieve successful continence. However, if they are still not dry for 3 hours during the day after the second year, bladder neck reconstruction has failed.

The bladder must also adjust to a new environment and new constraints. In addition, and probably more important, the patient must learn for the first time to recognize bladder filling and must be able to initiate voluntary detrusor contractions. With cooperation and time, urinary continence can be achieved in 71–74% of patients who have had a successful initial closure operation.[6]

If stress incontinence or dribbling is present 3–4 weeks after bladder neck reconstruction, the chance of obtaining adequate control is almost nonexistent. As noted, some patients gain continence with time, usually by increasing their bladder capacity and dry interval rather than by achieving better closure of their outlet. In male patients, growth of the prostate was formerly thought to help produce control of voiding. However, research by Gearhart and colleagues[53] showed that the prostate probably contributes little to the eventual attainment of continence.

Continuous postoperative dribbling typically indicates that further intervention will be required. Although the injection of substances (e.g., bovine collagen and dextranomer/hyaluronic acid [Deflux]) into the bladder neck after modified Young-Dees-Leadbetter bladder neck reconstruction is simple and safe, and although this approach has been used to try to improve continence, the success rate is approximately 45%.[54,55] Unfortunately, this procedure is typically not sufficient to create continence and should be used only as an adjunct to bladder neck reconstruction.

Bladder neck reconstruction can be repeated a second time if it fails. However, bladder capacity must be superb and urodynamic studies must reveal a stable bladder with absence of uninhibited contractions. In a series by Gearhart and colleagues,[56] only 50% of patients with failed prior bladder neck reconstruction were candidates for reoperative surgical procedures. In this highly selected group, continence rates (dry day and night) were approximately 85% after the reoperative bladder neck repair. All these patients had excellent bladder capacity (>100 mL) and stable function demonstrated on urodynamic examination before the reoperation.

Hydronephrosis can persist after bladder neck reconstruction and reimplantation. Careful follow-up to provide frequent evaluation of the upper urinary tract must be undertaken to prevent this complication. If hydronephrosis occurs and a small bladder capacity persists, bladder augmentation can be performed to protect the urinary tract and to achieve improved continence. In a review by Surer and colleagues,[57] 91 patients whose bladder exstrophy reconstruction failed required either bladder augmentation or continent urinary diversion. Of these patients, 62 had undergone previous bladder neck reconstruction but remained incontinent because of small bladders that did not grow after bladder neck reconstruction. None of these patients had reflux after their failed bladder neck procedures.

Treatment options in this group of patients include the following:

1. Placement of an artificial urinary sphincter and bladder augmentation
2. Reoperative bladder neck repair

3. Bladder augmentation with or without continent abdominal stoma
4. Continent stoma along with bladder augmentation and bladder neck transection or replacement.

The prospect of reoperation around the bladder neck after earlier failed surgical procedures makes the artificial sphincter and reoperative bladder neck procedures less attractive. However, in a bladder without reflux, the bladder neck can usually be transected safely and the bladder used as a template for augmentation and continent stoma construction.

In a series of 35 patients with bladder exstrophy who had multiple treatment failures, when the bladder capacity was >50 mL, reimplantation of the ureters into the bladder template and stoma creation were usually possible.[58] In these patients, when the bladder capacity was <50 mL, a continent stoma was implanted in the taenia of the bowel used for reconstruction and the ureters were reimplanted into the bladder template. In some cases, bladder capacity after treatment failure was so small that the entire bladder was replaced and the stoma channel was implanted into the neobladder. No major complications occurred in this group of patients. Therefore we believe that in patients with failed exstrophy reconstruction, augmentation cystoplasty or continent urinary diversion provides prolonged stability in the upper urinary tract and continence, and this approach has proved a successful alternative to urinary diversion.

Finally, stones can form in the urinary tract after bladder neck repair. In a series of 67 bladder neck repairs, bladder stones developed in seven patients and renal stones in one patient.[6] Most of these patients had difficulty with urinating after bladder neck repair and required prolonged suprapubic drainage. Thus, proper hydration and tube removal as soon as possible may aid in decreasing stone formation after bladder neck repair.

Long-Term Considerations

PENILE APPEARANCE

Most patients in our series had not reached adulthood and therefore may ultimately develop problems that occur in older patients. Some older patients seen at Johns Hopkins Hospital have problems pertaining to their exstrophy repair. Most of these young adults handle their problems well. However, the most severe problems are encountered in patients who underwent urinary diversion previously.

Certainly, penile shape and size are problems for some of these patients. Although many patients make good and imaginative use of their phallus, others voice concerns about its short and broad appearance. In addition, certain patients complain of residual chordee. Some patients have been counseled and learned to live with their problems and others have undergone surgical treatment with neophallus creation, depending on their emotional and penile status.

The penile lengthening procedure, as described by Johnston,[59] can be performed in adulthood to achieve a more dependent penile position, especially in the patient who has undergone previous urinary diversion. Sometimes, these patients can obtain greater length (usually ≈1 inch) by a repeat penile lengthening procedure, which must be carefully performed. Persistent dorsal curvature can also be corrected by dermal grafts used as corporal substitutions, which can be especially helpful in achieving a straight penile length when disproportion exists in size and length of the corporal bodies.

In an article by Mathews and colleagues from our institution,[60] the use of subcutaneously placed tissue expanders was found to be of great benefit in adults and adolescents with a history of bladder exstrophy. Penile skin can be stretched, and a considerable amount of new penile skin can be achieved in this manner. All remaining remnants of the suspensory ligaments and scars are radically excised and the penis is covered again with the newly generated penile skin. This procedure has been especially helpful in patients who have lost skin on one side of the penis or who have an overall paucity of skin secondary to surgical procedures in infancy and childhood.

PENILE AND INTROITAL DIFFICULTIES

Another problem encountered in older patients is ejaculatory dysfunction. Again, many patients who underwent previous urinary diversion may have a seminal fistula located in the mons area at the base of the penis. Ben-Chaim and associates[61] measured seminal volumes in 16 patients who were voiding through the urethra and found that 10 reported an ejaculatory volume of a few millimeters, three ejaculated only drops, and three had no ejaculations. Overall, patients with a history of bladder exstrophy ejaculate only small amounts compared with their physiologically normal contemporaries.

In adolescent female patients, the anterior location of the vaginal introitus can cause difficulty with sexual intercourse. A relaxing incision can often be made to facilitate intromission. Great care must be taken, however, because uterine prolapse has been reported after these procedures. These patients typically have short and wide vaginas, similar to the penises seen in male bladder exstrophy, and the cervix is very near the vaginal introitus. In girls who have not had an osteotomy, when one opens the vaginal introitus to make it suitable for sexual intercourse, the uterus sometimes descends, even in virginal female patients. In this case, we perform abdominal sacral colpopexy using a synthetic sling to allow sexual intercourse and pregnancy.

Many patients present with a bifid clitoris and a less than ideal appearance of the mons and surrounding area. Both uterine prolapse and an unsuitable appearance of the external genitalia appear to be less common in those patients who underwent osteotomy in the newborn period. When the pubic bones have been brought together in proper apposition, a mons-like appearance above the genitalia is created that facilitates subsequent feminizing genitoplasty without tension. Many of these female patients want a more cosmetic appearance to this area at puberty. Skin flaps and tissues expanders have been used in this area with great success.

FERTILITY AND PREGNANCY

Reconstruction of the male genitalia and preservation of fertility were not primary objectives in the early surgical

management of bladder exstrophy. Many accounts of pregnancy in female patients and impregnation by male patients with bladder exstrophy have been reported. In a review by Shapiro and associates[62] of 2500 patients who had undergone exstrophy and epispadias repair, 38 male patients had fathered children and 131 female patients had given birth. Ejaculatory fertility is rare in patients with a history of bladder exstrophy. However, in our database of >890 patients with bladder exstrophy who we have treated and followed up, we have had 18 patients deliver healthy babies with in vitro technology, and so far none of the newborns has had bladder exstrophy. In an article by Mathewset al.,[63] sexual function and pregnancy were normal in a selected group of female patients.

Libido in patients who have undergone bladder exstrophy repair remains high. The erectile mechanism in patients who underwent epispadias repair appeared intact in >90% of patients in our series who had erections following epispadias repair.[64] In a series of adult patients with long-term follow-up, all the women had normal and regular menstrual periods.[61] All these women had serious long-term relationships and were sexually active. Most experienced orgasm.

As mentioned previously, surgical complications include cervical and uterine prolapse. These young women must be informed of the likelihood of uterine and cervical prolapse even after one pregnancy. Birth by cesarean section is mandatory for women who have undergone closure and bladder neck repair or continent urinary diversion, to alleviate stress on the pelvic floor and to avoid trauma to the surgically reconstructed lower genitourinary tract.

MALIGNANT DISEASE

Most reported malignant diseases have occurred in patients with exstrophies that were left unclosed.[65] The most common tumor is adenocarcinoma, often resembling colonic malignant disease on immunohistochemical staining.[66] Investigators have suggested that rests of ectopic colonic epithelium serve as the origin of these adenocarcinomas.[67,68] Published case reports and other sources found rhabdomyosarcomas in three patients with bladder exstrophy.[69,70]

The inherent malignant potential of the closed exstrophic bladder has not been determined because long-term follow-up of a large cohort of patients with bladder exstrophy without urinary tract infections, obstruction, or chronic irritation has not been published. In an article by Novak and colleagues,[71] polyps associated with bladder exstrophy were evaluated pathologically and were found to be either fibrotic or edematous. Cystitis glandularis was often described, typically in polyps removed from bladders undergoing secondary exstrophy closures. Although no dysplasia was noted, cystitis glandularis is associated with adenocarcinoma of the bladder, and we believe these patients warrant surveillance with routine urine cytologic and cystoscopic examination as they enter adult life. We must be prudent and maintain a high index of suspicion until long-term studies become available.

Adenocarcinoma of the colon adjacent to the ureterointestinal anastomosis in ureterosigmoidostomy as well as in trigonocolonic diversion has been reported.[72,73] Gittes[74] calculated the long-term risk of developing a malignant tumor in the ureterosigmoidostomy at approximately 5%. In a study of patients who had a ureterosigmoidostomy for >15 years, the risk was found to be 11%.[75] In this study the risk of developing malignant tumors at the ureterocolonic anastomosis by 36 years of age was 11%. However, a more recent study with >30 year follow-up found only one malignancy in 13 patients with ureterosigmoidostomies still intact.[76] Although these types of urinary diversions are not commonly performed in North America at this time, we still see one to two patients a year with rectal cancer secondary to ureterosigmoidostomy. Thus, any patient who has a ureterosigmoidostomy should have an annual colonoscopy.

SOCIAL ADJUSTMENTS

Studies have shown that these patients are relatively normal and well-adjusted with good psychological integration and a positive attitude toward life.[61,77] However, the exstrophy-epispadias complex may be associated with an increased risk of anxiety disorders.[78] A recurring theme in all these patients is concern about penile length and chordee. The main objective of surgical intervention in bladder exstrophy repair is to enable these patients to achieve normal social interactions with their families and communities. With continuing excellent results of MSRE, it is gratifying that great progress has been made toward the realization of this goal.

Conclusions

This review of the complications of all methods of modern treatment of bladder exstrophy emphasizes the complexity of reconstruction of the bladder exstrophy spectrum. In experienced hands, the surgical results of primary bladder closure, epispadias repair, and bladder neck reconstruction are quite acceptable. A review of MSRE by Baird and Gearhart demonstrated that a secure abdominal wall closure, urinary continence, preservation of the upper urinary tract, and a cosmetically acceptable penis can be achieved in patients with a successful primary closure and in a reasonably high percentage of patients with an unsuccessful primary closure.[6] Similarly, in a review by Gearhart and associates,[58] all 35 patients in whom bladder exstrophy reconstruction failed were doing well following bladder augmentation or continent stoma. Therefore, although complications such as dehiscence, deterioration of renal function, and fistula do occur, with careful attention to surgical detail and frequent follow-up, these patients can have a normal childhood and can become contributing members of society.

Acknowledgment

This chapter is dedicated to the memory of Robert Douglas Jeffs, MD, FRCS(Can) (1924–2006), Emeritus Professor of Pediatric Urology at the Johns Hopkins Hospital in Baltimore, a respected teacher, colleague, and friend.

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Chapter 59 Questions

1. All of the following should be routinely used for closure of an exstrophic bladder, except:
   a. Combined anterior innominate and vertical iliac osteotomy for reclosure of failed primary closure
   b. Radical mobilization of the bladder from the pelvic floor musculature
   c. Ureteral stent and suprapubic tube drainage
   d. Continuous, postoperative traction via Buck's or Bryant's traction
   e. Paraexstrophy skin flaps for urethral lengthening

2. At what point can an eroded intrapubic stitch be safely removed?
   a. 1 month
   b. 2 months
   c. 3 months
   d. 4 months
   e. >1 yr

3. Which of the following is the most appropriate style and size of suture for an intrapubic stitch?
   a. #0 polypropylene
   b. #2 polydioxanone
   c. #2 nylon
   d. #2 polypropylene
   e. #0 silk

4. Penile tissue loss is associated more commonly with which type of surgery?
   a. Modern stage repair of exstrophy
   b. Modified Cantwell–Ransley epispadias repair
   c. Bladder neck reconstruction
   d. Complete primary repair of exstrophy
   e. Augmentation cystoplasty

5. After primary repair of exstrophy, routine use of which imaging modality for postoperative monitoring of the urinary tract is advised?
   a. Renal ultrasound
   b. Voiding cystourethrogram
   c. Nuclear medicine scan
   d. a and b
   e. All of the above

6. What bladder capacity is generally considered adequate for using at least some part of the bladder as part of a continence procedure?
   a. 100 mL
   b. 10 mL
   c. 20 mL
   d. 30 mL
   e. 50 mL

7. At what point should continence surgery be considered?
   a. The child is at least 5 years of age
   b. The patient and parents have had excellent preoperative counseling regarding bladder neck reconstruction
   c. The child has expressed interest in being dry
   d. All of the above
   e. None of the above

8. Which of the following can be used for achieving additional penile length after puberty?
   a. Penile lengthening with skin release and division of the suspensory ligaments
   b. Penis transplant
   c. Neophallus creation with radial forearm flap
   d. Penile prosthesis implantation alone
   e. a and c

9. Which of the following is a concerning finding on follow-up after successful primary repair of exstrophy?
   a. Persistent urine leakage from the epispadias
   b. Asymptomatic bacteriuria found on bagged urine culture
   c. Reflux seen on cystogram
   d. Prolonged dry interval
   e. No hydronephrosis noted on ultrasound

10. If large residuals are obtained from the suprapubic tube after primary repair, the first step in evaluation should be:
    a. Cystoscopy
    b. Renal ultrasound
    c. Voiding cystourethrogram
    d. Percutaneous nephrostomy tube placements
    e. Immediate surgical exploration of the urethral closure

Case Studies

CASE 1

A 3-year-old boy is referred to your practice after recent adoption from China. He had closure in his home country near birth with posterior iliac osteotomies. Upon examination, a small vesicocutaneous fistula is seen above the epispadias.

1. After newborn exstrophy closure, appropriate immobilization of the pelvis is important for which of the following reasons?
   1. To keep the pelvis rotated medially
   2. To keep shearing forces from distracting the pubic closure laterally
   3. To take tension off the midline closure
   4. To keep the lower extremities in the midline
   5. To keep the pelvis flat on the bed
      a. 1 and 3
      b. 2 and 4
      c. 1, 2, and 3
      d. 3 and 5
      e. All of the above

2. When the initial exstrophy closure fails with complete dehiscence, what is the most appropriate next step?
   a. Immediate reclosure with pelvic osteotomy, even if previously performed

b. Place the child in immediate modified Bryant's traction with Buck's skin traction
c. Cover the bladder with moist gauze and reclose in 6 weeks
d. Perform a cutaneous vesicostomy
e. Allow healing for 4 to 6 months and then reclose with pelvic osteotomy and proper immobilization for 6 weeks

3. The most appropriate next step in management is:
a. Operative intervention with closure of fistula
b. Closure of fistula with concomittent epispadias repair to improve bladder growth
c. Immediate reclosure with bilateral iliac and innominate osteotomies
d. Exam under anesthesia and cystoscopy
e. Observation until appropriate for continence procedure

CASE 2

A 10-month-old boy presents to your clinic with his parents for second opinion of bladder exstrophy. He has a history of failed exstrophy repair at birth without osteotomy, followed by revision of closure with anterior innominate osteotomy at 2 weeks of age.

1. Which of the following physical exam findings would be concerning for failed closure?
a. Pink tissue visible at the base of the epispadias that becomes more prominent with crying
b. A low umbilicoplasty
c. A palpable bladder
d. A right-sided inguinal hernia
e. A short, wide penis

2. After successful reclosure with concomitant epispadias repair, which option(s) should routine follow-up include? (Select all the correct answers)
a. At least yearly renal ultrasound
b. Voiding cystourethrogram
c. Nuclear medicine renal scan
d. Yearly operative cystoscopy and cystogram
e. Yearly basic metabolic panel

3. The patient now presents at 10 years of age with his parents greatly desiring to be continent of urine. Before proceeding to surgical correction of incontinence all of the following should play roles in the treatment plan except:
a. Prior failed closures
b. An assessment of willingness of patient and parents to adhere to rigorous treatment plans by physicians, experienced nursing, and child psychologist
c. Penile length
d. Bladder capacity
e. Constipation

Answers

1. **e**. Though previously used for lengthening of the posterior urethra routinely, the risk of posterior urethral stricture is too high to recommend routine use. Use in select cases where the verumontanum lies in close proximity to the glans is advised, and careful attention to using full thickness flaps with minimal manipulation with forceps is mandated.
2. **d.** After 4 months the osteotomies have adequately healed to keep the pelvis in place, and a strong intrapubic bar has developed, negating the need for continued apposition of the pubic tubercles with a stitch.
3. **c.** #2 nylon suture provides the best load-to-failure ratio among several methods of pubic approximation using various commonly employed suture materials.
4. **d.** Significant penile tissue loss has been seen most commonly with complete primary repair of exstrophy (CPRE). Penile loss is also seen with primary exstrophy repair without osteotomy due to vascular congestion at the pubic closure.
5. **a.** Routine use of ultrasound is indicated to follow for upper tract changes. Other imaging modalities should be employed if upper tract changes are noted, and tailored to the patient's clinical status, but should not be used as routine follow-up imaging.
6. **a.** Bladder capacity around 50 mL is adequate for use of the bladder as part of a continence procedure, typically for ureteral reimplantation with augmentation and catheterizable channel implanted into the augment. Less than this volume makes reimplantation with adequate tunnel length difficult to impossible.
7. **d.** Continence procedure is a significant undertaking for both the exstrophy patient and surgeon. This requires willingness on the part of the parents and patient for timed voiding, cathing regimens, etc.
8. **e.** Both radical dissection of the penis and neophallus should be considered and tailored to the individual placement. Though inflatable penile prosthesis (IPP) placement is necessary with neophallus, IPP alone will further shorten the exstrophic penis. Though penile transplant is under investigation by several centers, it is not currently considered for exstrophy patients.
9. **d.** When bladder outlet obstruction is suspected, a renal and bladder ultrasound should be performed immediately to assess for hydronephrosis and/or an enlarged bladder.
10. **a.** If large residuals are encountered after closure and removal of traction and ureteral stents, posterior urethral stricture must be considered. This can be due to a variety of causes, and cystoscopy allows for the most direct way to evaluate. Treatment can then be determined from the etiology seen on cystoscopy.

CASE 1

1. **e.** Proper immobilization provides for medial rotation of the pelvis, reduces lateral distraction and tension, and keeps the lower extremities midline and the pelvis flat. Patients who are closed without pelvic osteotomy are kept in external fixation with modified Bryant's traction for 4 weeks; those with osteotomies are kept in external fixation and modified Buck's traction for 4 weeks in primary closures and 6 weeks in secondary closures.
2. **e.** When initial exstrophy closure is complicated by complete dehiscence, it is prudent to wait until the

infant is 4–6 months of age, allowing both the child and the bladder to grow, and then undertake reclosure with bilateral pelvic osteotomies. At this time epispadias repair also may be performed under testosterone stimulation in many male patients.

3. **d.** When a vesicocutaneous fistula is found after primary closure, one should have a high index of suspicion for failed closure with fascial dehiscence. The most appropriate step would be to evaluate the child's anatomy under anesthesia with an attempt for cystogram to check capacity/growth since birth. Careful attention should be paid during cystoscopy for position of the bladder, especially with visualization of the cystoscopy light through the skin. Given the high likelihood of failed closure and re-diastasis, one should be prepared for reclosure only once the examination under anesthesia and cystoscopy confirm the diagnosis.

CASE 2

1. **a.** This scenario represents prolapse of the bladder into the urethra with abdominal straining. This is due to failure of the fascial and pelvic closure allowing the bladder to be too anterior in the pelvis, thus creating hypermobility with abdominal pressure. A palpable bladder would make one concerned for outlet obstruction. Though inguinal canals should be explored, and repaired at closure, a recurrent hernia does not indicate a failed repair.
2. **a and d.** Monitoring of the upper tracts for deterioration should be done with renal ultrasound to evaluate for signs of obstruction that can be intervened upon before changes in creatinine may be seen. Also, operative cystoscopy and cystogram are done to evaluate for bladder growth, vesicoureteric reflux (which is common), bladder quality, and urethral quality for both immediate management (antibiotic prophylaxis for reflux) and future surgical planning/parent and patient counseling.
3. **c.** Though penile length is a problem for male exstrophy patients, continence procedures will not change length and thus do not play a role in readiness for such operations. Failed closures and bladder capacity help the surgeon to decide the appropriateness of bladder neck reconstruction versus diversion procedures, and need for augmentation. Voiding programs with rigorous assessment of bowel voiding habits should be done prior to undergoing any continence surgery.

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60 Complications of Hypospadias Repair

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CHAPTER OUTLINE

Prevention of Complications
Preoperative Evaluation
Timing of Repair
History and Physical Examination
Operative Technique
Postoperative Care
Management of Complications
Early Postoperative Complications
Ischemia
Bleeding and Hematoma
Wound Infection
Wound Separation
Late Postoperative Complications
Urethrocutaneous Fistula
Urethral Stricture
Urethral Diverticulum
Meatal Complications
Persistent Chordee
Other Urethral Problems
Psychological Consequences
Complex Hypospadias
Conclusions
Chapter 60 Questions and Answers

KEY POINTS

1. Hypospadias repair requires meticulous attention to detail, especially with regard to tissue handling and the creation of local tissue flaps.
2. When operating for complex hypospadias the surgeon must have a variety of techniques available to be able to tailor the operation to the needs of the patient.
3. When necessary, staging of the hypospadias operation may provide adequate time for graft healing and chordee corrections, thus facilitating more effective urethroplasty at a second stage.
4. Use of a barrier layer with local tissue is crucial for reinforcing the urethroplasty and for preventing the formation of fistulas.
5. When evaluating a hypospadias complication, the surgeon should be careful to address all factors that may have contributed to the complication and not just the complication in isolation.
6. In a boy with a complication, the surgeon must be willing to completely revise the repair if other treatments would leave the patient less than satisfied or at high risk for a second, later complication caused by correction of the initial complication.

Duckett tabulated his experiences with hypospadias repair to coin the term *hypospadiology*.[1] His intent was to highlight the complex interplay of both art and science that results in a successful hypospadias repair. Since the first modern descriptions of hypospadias repair in the mid-19th century, the surgical management of this defect has undergone a remarkable evolution to improve functional outcomes and minimize complications.[2]

Despite continued advances, successful penile reconstruction for hypospadias repair remains one of the most challenging areas within the field of pediatric and reconstructive urology. A combination of factors threatens to compromise even the most meticulous repair. The structures are delicate and the healing process is dependent upon neovascularization in spite of surgical reconstruction. Postoperative edema, the risk of infection, the inherent variability in the healing process, and the potential for patient harm by early catheter removal creates a complex environment with risk for failure.

A rigid surgical approach to the spectrum of hypospadias will be uniformly successful in this environment of complex penile reconstruction. Nevertheless, it is important for anyone who undertakes this type of surgical procedure to have a thorough understanding of the potential pitfalls in the workup, surgical management, and postoperative care of these patients. This chapter discusses the approach to prevention and management of hypospadias complications with reference to commonly used techniques.

Prevention of Complications

Hypospadias repair is complex and should be performed by pediatric urologists that have undergone specific training and have sufficient experience.[3] Expertise is not achieved at the completion of a fellowship alone, but this training combined with increasing surgical volume significantly improves outcomes. In a study following a single surgeon's experience, the complication rates in 231 consecutive patients over a 5-year period were examined, beginning immediately post fellowship. The investigators demonstrated a significant decrease in urethrocutaneous fistula development each successive year following training.[4] Similar studies have directly correlated less experience and surgical volume with increased risks of complication development.[5,6]

The best treatment of hypospadias complications is through prevention. Penile reconstruction is a complex art form that requires a complex blend of experience, the ability to utilize a wide variety of techniques dependent upon the unique presentation, and safe handling technique. In spite of meticulous technique, patient factors such as wound healing and tissue ischemia can result in complication development. An understanding of the technical factors predisposing patients to failure aids in their prevention. We therefore begin our discussion with a specific emphasis on the workup, surgical technique, and perioperative care of these patients.

PREOPERATIVE EVALUATION

Timing of Repair

To facilitate a successful repair the ideal age for hypospadias repair must be identified by balancing the adverse psychological effects of surgery, the anesthetic risk to the child, and the degree of penile growth. Genital awareness begins to occur around 18 months of age and progresses with increasing age.[7] Several investigators reported that patients undergoing earlier repair (usually <12 months of age) experienced less anxiety and had improved psychosexual outcomes when compared with older children undergoing hypospadias repair.[8,9] Patients operated on at a younger age may also experience fewer complications, a finding that reinforces the need for early correction.[9] We counsel all parents that at 6 months of age anesthesia risks are equal to those of older children and adults, allowing hypospadias repair to be performed as an outpatient. Based on these studies, the American Academy of Pediatrics Section on Urology suggested that the optimal time for hypospadias repair is between 6 and 12 months of age.[10]

Parents often raise questions about the safety of anesthesia exposure in young children. Data in animal models suggest varying degrees of neurotoxicity in response to agents commonly utilized for general anesthesia.[11] These studies are difficult to replicate in human subjects but longitudinal analysis of children exposed to anesthesia (general vs regional block) resulted in no detectable neurodevelopmental delays at 2 years of age.[12] Although far from conclusive, it appears that there are no consequences of a single anesthesia exposure at short-term follow-up.[13]

History and Physical Examination

The initial evaluation of patients presenting for hypospadias repair requires a careful history and physical examination. In the patient without previous surgery, the history is directed toward identification of coexistent anomalies that could affect surgical care. The inquiry should focus on a history of prior urinary tract infections (UTIs), voiding dysfunction, and any associated medical diseases that may complicate care, such as asthma or a bleeding diathesis.

Patients with a history of other global systemic anomalies should be considered for evaluation with a screening ultrasound for the presence of associated urinary tract abnormalities.[14] The physical examination focuses on staging the phenotype to assess the degree of severity. This includes the degree of chordee, the location of the urethral meatus, the quality of the urethral plate, and the amount of skin for reconstruction.[15] These factors play a significant role in the surgical planning process and potentially increase the risk for complication development. Finally, patients with unilateral or bilateral undescended testes, perineal hypospadias, or ambiguous genitalia must undergo additional workup to rule out a disorder of sexual differentiation, which occurs much more frequently in this setting.[16–19]

A glans size of 14 mm or less at the time of surgical repair has been associated with increased risk for complication occurrence.[20] Preoperative testosterone can be given to increase glans width and penile length.[21,22] Whether this decreases the postoperative complication rate remains controversial, but given the risk associated with a smaller glans, increasing its width has potential benefits.[23,24] Our practice is to administer intramuscular testosterone in the setting of a small glans (14 mm) at 6 and 3 weeks prior to planned surgical intervention.

Surgical planning continues after the induction of anesthesia. Following antiseptic preparation of the genitalia and administration of intravenous antibiotics, the genitalia are carefully examined again to classify the hypospadias phenotype and to determine the surgical approach. We do not find it necessary to perform routine cystoscopy except in cases of severe proximal hypospadias or salvage operations. Prostatic utricles occur in >10% of patients, more frequently in proximal hypospadias, and therefore cystoscopic examination may be useful in these particular situations to facilitate catheter insertion.[25] Alternatively, catheter placement over a wire typically results in successful catheter insertion in the setting of a prostatic utricle.

Options for regional block include caudal vs penile blockade. There has been some recent focus upon the potential for increased complication rates for patients undergoing caudal blockade, although this remains controversial.[26,27] When administered a second dose at the completion of the procedure can prolong the period of blockade.[28,29] At our institution we prefer caudal anesthesia when a block is administered for hypospadias repair.

OPERATIVE TECHNIQUE

The patient is placed in the supine position after the anesthesia block is performed. A glans holding stich is placed. The urethra is evaluated with a catheter or sound to determine the caliber of the opening and the quality of the

overlying skin, which can be hypoplastic, requiring repair in spite of appearing intact. A circumcision incision is then made and the penis is degloved. The initial step in treatment of penile chordee (orthoplasty) is excision of all chordee tissue to the level of the penoscrotal junction. The adequacy of resection can be assessed with saline injection[30] or pharamocologically induced erection.[31] This step is crucial as inadequate assessment and undertreatment of chordee can result in significant morbidity and poses a complex surgical problem.

Chordee release often results in migration of urethral meatus to a more proximal location. Although several hundred techniques have been described in the literature, urethroplasty techniques can be broadly categorized as those using flaps of local genital skin, those using flaps or grafts of preputial or extragenital tissue, and urethral tubularization. In a survey of pediatric urologists, the tubularized incised plate technique was utilized >90% of the time for distal hypospadias repairs and 80% of the time for midshaft repairs.[32] Numerous techniques are available for the management of proximal or complex hypospadias, and selection of approach is beyond the scope of this chapter. The use of hair-bearing skin is discouraged because it renders the neourethra susceptible to stone formation and recurrent UTIs.

Surgical technique is as important a factor for outcomes as surgical approach. Gentle tissue handling prevents crush injury and preserves blood supply to tissues, which is crucial to complication prevention. Ischemia results in fibrosis and contraction of tissues, predisposes patients to infection, and potentiates the breakdown of suture lines. Tissue trauma can be minimized by the use of fine forceps, skin hooks, and stay sutures. Intraoperative magnification facilitates this process and helps to identify the delicate blood supply of flaps. Flaps must be mobilized generously to minimize tension on suture lines and to prevent ischemia. Subcuticular neourethral approximation with epithelial inversion has been shown to decrease complications when compared with full-thickness approximation.[33,34] For urethroplasty we prefer a fine absorbable monofilament such as polydioxanone (PDS), polyglactin (Vicryl), or polytrimethylene carbonate (Maxon). Next, the use of multiple tissue layers is vital in the reduction of complications. Dartos interposition flaps increasing the vascularized layers above the repair reduce fistula formation after tubularized incised plate repair (Fig. 60.1).[35]

Finally, careful hemostasis should be maintained with the judicious use of pinpoint cautery and a compressive bioocclusive dressing (Fig. 60.2). This dressing can be formed from an adhesive membrane such as Tegaderm, which is applied circumferentially from the level of the glans to the penoscrotal junction. The glans must be included in the dressing to avoid excessive swelling. Care must be taken to prevent a constricting ring at the proximal extent of the dressing. Alternatively, we also use a sandwich dressing, which works in a similar fashion by restricting the penis toward the body for the first 72 hours post surgery.

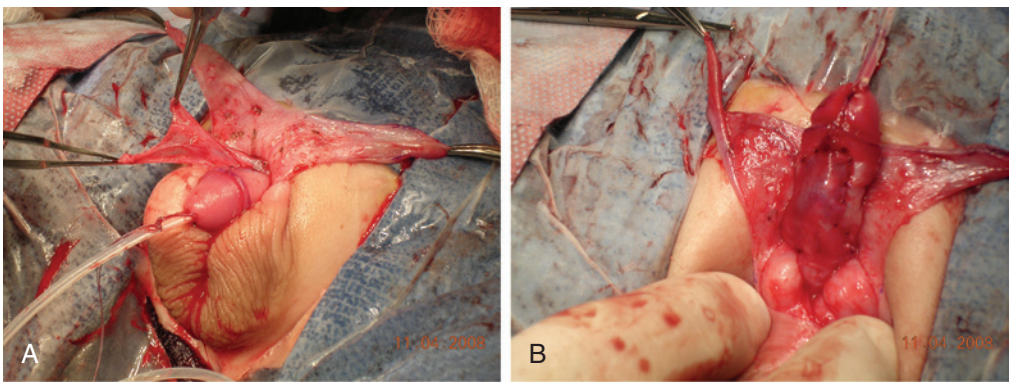


Figure 60.1 Dartos flap for second layer urethral coverage. A, Harvesting of the dartos flap from the dorsal preputial skin. B, Placement of the flap over the newly tubularized urethra.

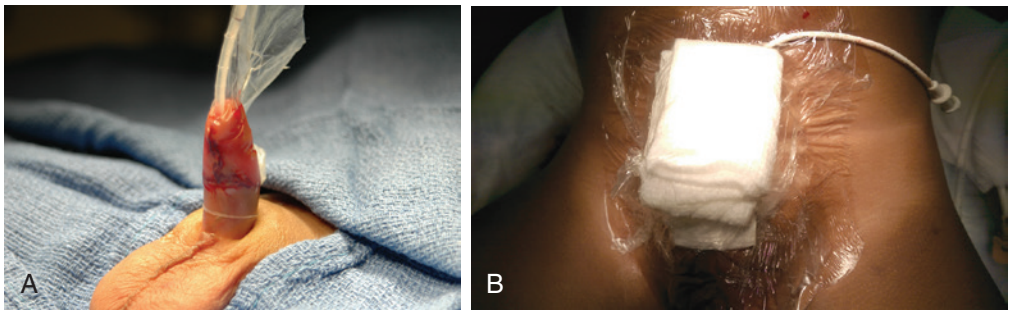


Figure 60.2 Dressing for hypospadias repair. A, Transparent adherent dressing (Tagaderm) is applied from the glans to the level of the penoscrotal junction, with care taken to prevent a constricting band at the proximal extent. A 6 or 8Fr silicone urethral stent is sutured to the glans to allow free passage of urine. B, Sandwich dressing compressing the penis against the body with a loose fitting Tagaderm overlying a Telfa gauze. The urethral catheter can be sutured in place for prolonged diversion or secured temporarily until the dressing is removed.

POSTOPERATIVE CARE

Good postoperative care is essential. An excellent surgical repair can be inadvertently compromised with poor management. Options for methods of urinary diversion, dressings, and perioperative medication administration have varied greatly throughout the history of hypospadias management. Options for urinary diversion include urethral stents, urethral catheters, and suprapubic tubes or a combination thereof and are intended to minimize stress to the urethroplasty in the immediate postoperative period. Particularly for complicated repairs, urethral diversion has been shown to decrease rates of meatal stenosis and urethrocutaneous fistula development.[36,37] Catheters must be well secured before the patient leaves the operating room, and indwelling duration ranges from 1 to 3 weeks.

Regional block via either a caudal regional block or a circumferential penile block reduces narcotic requirement both in the operating room and the immediate postoperative period.[38] As mentioned above, some reports suggest an increased risk of complications when caudal block is used, but this remains controversial and we routinely use caudal blocks at our institution.[26] The effect can be improved when blocks are performed prior to and just after the procedure.[28,29] In addition, ketorolac (0.5 mg/kg), given as a single dose 30 minutes before the conclusion of the procedure, is a safe and effective adjunctive pain medication that is associated with less emesis than are opioid analgesics.[38,39]

Postoperatively, bladder spasm is common after urethroplasty and can result in high-pressure voiding around stents and catheters, placing undue stress on the urethroplasty. This can be alleviated with an anticholinergic agent such as oxybutynin, which is started in the postoperative period and continued until 24 hours before removal of the urethral stent. Perioperative antibiotics are routine practice, and prophylactic antibiotics during the postoperative catheterization period have been shown to reduce postoperative complicated UTI and thus potentially to decrease overall fistula and stenosis rates.[40–42]

Management of Complications

EARLY POSTOPERATIVE COMPLICATIONS

Ischemia

Tissue ischemia occurs to some degree with all reconstructions performed for hypospadias and is responsible for most of the complications that occur. Ischemia potentiates edema and infection, delays wound healing, and promotes fibrosis. Common techniques in urethroplasty employ either the transfer of tissue island flaps that are dependent upon a delicate blood supply or grafts that must rely on the quality of the vasculature of the recipient tissue bed. These tissues are at risk for ischemic changes that can lead to tissue breakdown, which can result in the formation of a urethrocutaneous fistula or stricture. In a similar fashion, ischemia of flaps used for skin coverage, particularly in the setting of large deficits, can lead to necrosis, eschar formation, and wound contraction (Fig. 60.3). Advances in technique have decreased the incidence of this complication in our experience. A ventral penile incision that extends to the penoscrotal junction frees the dorsal skin and increases exposure of the vascular pedicle. Holding sutures place tension on the flap, further identifying the vascular pedicle to ensure preservation during dissection.

Thoughtful operative technique can usually prevent ischemic complications by minimizing postoperative edema or hematoma formation. Flaps must be harvested with adequate blood supply and without tension. High-powered visual magnification with loupes aids in pedicle identification and preservation, while gentle retraction with holding sutures minimizes tissue trauma. Ideally, poor tissue perfusion is discovered during the procedure, though this is often not the case. Tissue edges that blanch when sutured indicate excessive tension and should be taken down and reapproximated. Despite meticulous technique, ischemia to the penile skin may not become apparent until after removal of the dressing. Treatment is initially conservative with liberal application of petroleum jelly. Necrosis of skin flaps is usually partial, as long as a healthy layer of dartos tissue is present. The eschar will necrose and the defect will gradually re-epithelialize. If a clearly demarcated edge exists, debridement of the eschar can be considered. Grafting and revision surgical procedures are rarely necessary and are reserved for wound contraction that results in chordee.

Bleeding and Hematoma

A wound hematoma can occur even with meticulous intraoperative hemostasis, though a compressive dressing typically limits its progression. In its most severe form, the mass effect of blood may distort tissue planes and interfere with perfusion of tissue flaps or prevent graft uptake.[43] A large hematoma can also result in skin separation or act as a nidus for infection, and resorption of the blood can result in inflammation, scarring, and fibrosis. A wound

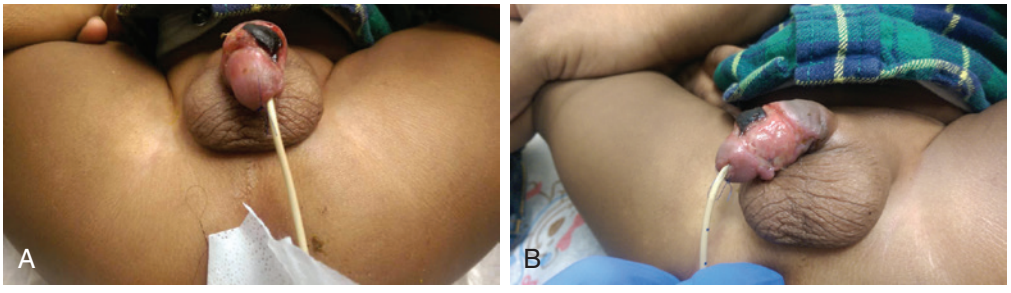


Figure 60.3 Example of eschar formation on penile shaft skin after transfer of dorsal inner preputial island flap transfer to compensate for lack of ventral shaft skin. Black area represents remaining eschar, which will slough with time. A supple underlying layer of dartos allows re-epithelialization.

hematoma increases risk for complications such as fistula, stricture, and recurrent chordee.

Hematoma management depends on its size and the time at which it is noted. A delicate balance is achieved between adequate hemostasis during the procedure and maintaining tissue perfusion. If a significant hematoma is present during the procedure at skin closure or with dressing placement, the skin should be opened, the clot evacuated, and the precise source of bleeding identified and controlled. In a patient with a large hematoma discovered early in the postoperative period, consideration should be given toward returning to the operating room for evacuation of the hematoma and placement of a drain, particularly if the surgeon believes that the hematoma may affect flap survival. Alternatively, reinforcement of the compression dressing in the setting of a nonexpanding hematoma can be performed with minimal consequence to the repair. Smaller hematomas rarely cause long-term problems and can usually be managed conservatively.

Wound Infection

Because of the superb blood supply of the genital structures, severe infections rarely occur after hypospadias repair. Nevertheless, poorly perfused flaps, skin grafts, and traumatized tissue can develop localized infections, secondary to gram-positive skin flora. These organisms predominate cultures of perimeatal tissues performed at the time of the surgical procedure.[44]

UTIs can also occur in the postoperative period. Typical urinary tract pathogens represent the etiology for most infections and some suggest that perioperative antimicrobial therapy combined with daily prophylaxis until after catheter removal decreases the risk for infectious complications.[45] This finding coincides with our practice of administering prophylaxis to our patients until all catheters are removed. When infections do occur, aggressive management is important to prevent inflammation, which can delay wound healing and predispose to fistula or stricture formation. Delayed UTI suggests poor urinary drainage and should raise concern for urethral diverticulum, meatal stenosis, and/or urethral stricture. Stent encrustation is a possibility in the setting of a proteus infection, although this typically isn't evident until the time of stent removal. If the stent isn't easily removed in the office then removal in a controlled setting under general anesthesia is warranted.

Superficial wound infections typically respond to oral antibiotics directed at gram-positive organisms. Escalating infection in spite of appropriate antibiotic therapy warrants inpatient admission for IV antibiotic administration for multidrug-resistant organisms. Wound cultures and urine cultures should be obtained when appropriate to guide antibiotic therapy. We find that UTI in the setting of a well-positioned and draining catheter is rare.

Wound Separation

The origin of separation of the penile shaft skin is multifactorial, with infection, ischemia, edema, and hematoma formation all potentially playing a role. When this occurs conservative management with liberal application of petroleum jelly to the defect allows closure by secondary intention with minimal morbidity, as long as supple dartos tissue is present. Attempts at suture placement are not recommended as these may require anesthesia and may exacerbate edema or inflammation. If wound disruption occurs several days postoperatively and is associated with excessive edema, the surgeon must entertain the possibility of a wound infection or urine extravasation.

LATE POSTOPERATIVE COMPLICATIONS

While outcomes for hypospadias repair are generally favorable, particularly for distal repairs, increasing intention is being given toward the need for long-term follow-up, particularly for proximal repairs where the complication rate can approach 60%.[46–48] Follow-up that does not extend into puberty underestimates our complication rate, in spite of what appears to be a successful outcome.[49,50] Standardization and extension of our follow-up protocols is vital and will allow us to ensure that we are achieving good outcomes for these boys not only in the immediate postoperative period but for their lifetime.[51]

Urethrocutaneous Fistula

Urethrocutaneous fistula is the most commonly reported major complication of hypospadias repair and increases in frequency with the increasing severity of hypospadias.[52] The incidence of fistula has decreased with the improvement in operative techniques.[53] An incidence of <10% for distal hypospadias repair is now to be expected.[49,52,54]

The development of fistula is a multifactorial phenomenon. As mentioned earlier, ischemia, edema, infection, and hematoma may contribute to improper healing of the neourethra. Distal urethral obstruction from meatal stenosis or urethral stricture results in high urethral pressures during voiding, placing undue stress proximally on the suture line. Technical factors such as overlapping suture lines, inadequate inversion of the epithelium, or use of poorly absorbable suture material play a role.[55] Finally, the severity of hypospadias plays perhaps the largest role in fistula formation.[20,56,57]

Management of urethral fistula depends on the number, size, location, and time interval from the surgical procedure. A urine leak usually becomes apparent with the generation of multiple urinary streams, and most are noticed within the first 2 years of surgical repair.[49,50,58] A fistula can be singular, with a patient presenting with two or multiple streams. Urine can be completely diverted out of the fistula site or as a fraction extending from the native urethra and the fistula. Finally, a pinpoint fistula can be more subtle in presentation, with a drop of urine during or after urination. In our experience, we have also observed children who present in a delayed fashion at toilet training, when the urinary stream is more likely to be consistently observed.

Small fistulas noted in the immediate postoperative period without concomitant inflammation or meatal stenosis may spontaneously close on their own or with the aid of catheter insertion.[59] Although this may be the case, the vast majority of urethrocutaneous fistulas require surgical repair, which is delayed until at least 6–12 months after the initial hypospadias repair to allow proper wound healing. This delay allows ingrowth and establishment of the vascular supply and resolution of inflammation and edema, maximizing the potential for success.

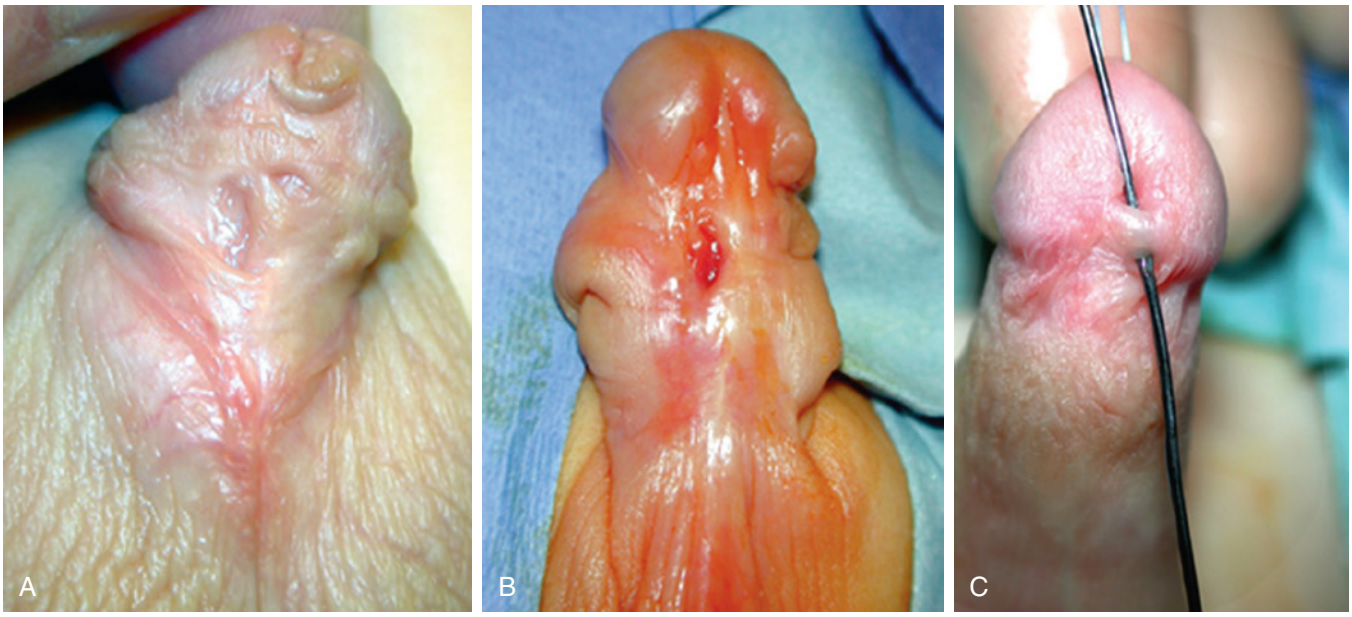


Figure 60.4 These children have large urethrocutaneous fistulas (A, B, C). C, Probe in a urethral fistula.

The first step in management of complications demands a careful evaluation to rule out any additional anomalies, such as persistent chordee, urethral stricture, and/or diverticula. The surgical approach is dictated by these findings, as well as by the size and location of the fistula. Intraoperatively, it is important to calibrate the urethra distal to the fistula with an 8 to 12Fr bougie à boule to ensure adequate caliber (Fig. 60.4). If any question remains about the anatomy a cystoscopy should be performed. The penile shaft must be evaluated for the presence of other unrecognized fistulas. The fistula tract can be cannulated with a lacrimal probe to determine the site of entrance into the urethra. In our hands a urethral catheter inserted to inject saline to perform a "stress test" will readily identify fistula tracts not visualized on examination.

Small-caliber fistulas on the penile shaft proximal to the coronal margin can potentially be closed primarily.[60] Prolene holding stitches are placed through the epithelialized tract, which is then excised in an elliptical fashion down to the urethra. The site is then closed primarily in a subepithelial fashion, and multiple overlapping layers are placed to prevent recurrence. Larger fistulas may require coverage with a trap-door or island flap of penile shaft skin. In general, better results have been achieved when a second layer or flap coverage in an offset fashion is utilized.[33,43,60] Skin coverage can be obtained by several methods to avoid overlap of urethral and skin suture lines (Fig. 60.5).

Fistulas at the coronal margin can prove to be more challenging. While it is tempting to perform excision and primary closure, a fistula at this site often represents a pathologic narrowing that requires takedown and revision of the distal urethroplasty. Failure to do so results in a high risk of failure.

Despite a well-performed repair, fistulas recur about 20% of the time.[3,61] This recurrence rate may be lessened with interposition of multiple well-vascularized nonepithelialized layers between the urethral closure and the skin. Redundant dartos tissue, if present, or a scrotal-based tunica vaginalis flap[62–64] may also be used. Scrotal dartos tissue has been used in a similar fashion.[65] A de-epithelialized flap repair is another technique that has shown promise.[60] There is no need to divert the urine for simple repairs, but for larger repairs we routinely divert the urine for 7 to 10 days.[60,66,67] Finally, in cases of severe fistula formation with a lack of local tissue for skin flaps, buccal mucosa grafts have been used with some success.[68] For challenging cases, particularly those with a history of multiple prior repairs with poor local skin and having undergone a buccal mucosa graft, we have had success with the Cecil modification to promote graft healing and additional vascular supply.[69] Release of the penile shaft from the scrotum after 12 months of healing typically reveals a supple urethroplasty and ample tissue for tension-free shaft skin coverage.

Urethral Stricture

Urethral stricture is the second most frequently reported complication of hypospadias repair, with rates varying according to urethroplasty technique and length.[70,71] These strictures tend to form at anastomotic suture lines, such as the urethral meatus or the proximal anastomosis of the native and reconstructed urethra. The clinical picture can vary, with strictures presenting with complaints of a diminished force of urine stream, stranguria, urinary retention, or urinary tract infection. Alternatively, some physicians note anomalous uroflow rates on routine follow-up after toilet training.

Several factors increase the risk of postoperative stricture. Improper urethroplasty technique, such as primary tubularization of a narrow urethral plate when an onlay may be indicated, can result in a conduit of insufficient caliber, place tension on suture lines, and narrow the anastomosis. Tissue ischemia, trauma, or infection can result in inflammation and concentric scarring of the lumen. In tubularized pedicle flaps, a stricture may be functional, secondary to a redundant neourethra kinking at the proximal anastomosis. It is best to characterize the stricture via

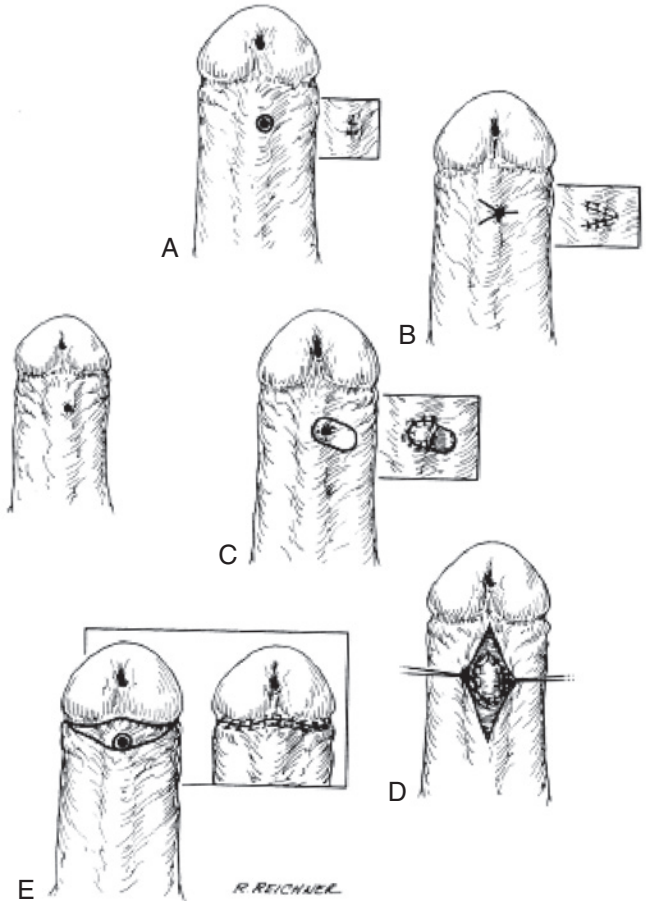


Figure 60.5 Techniques of fistula repair after hypospadias correction. A, Excision and primary closure. B, Y-V skin advancement after excision and closure of the fistula. C, Trap-door flap of penile skin. D, Full-thickness patch graft. E, A small coronal fistula is excised and penile shaft skin is advanced to cover the defect. (With permission from Winslow BH, Vorstman B, Devine CJ: Complications of hypospadias repair. In: Marshall FF, ed. Urologic Complications: Medical and Surgical, Adult and Pediatric. Chicago: Year Book; 1990.)

cystoscopy while the patient is under anesthesia to carefully delineate the length, caliber, and location of the stricture and to evaluate for any additional complications.

Initial management depends upon the severity of the stricture. For short strictures causing minimal symptoms, a single try at urethral dilation or endoscopic treatment is appropriate. In most cases, however, this will not provide a long-term solution. Direct visual internal urethrotomy in adult strictures has low success rates and risks worsening the stricture by generating worsening inflammation and scar.[72] Success rates for small strictures (<1 cm), even when done in conjunction with intermittent catheterization, are poor, with only approximately 20% of patients exhibiting a normal flow rate 2 years post incision.[71] These investigators reported success rates of 72% (onlay urethroplasty) and 63% (urethral plate urethroplasty) for strictures, suggesting that this approach may have some utility in these patients. The outcome may be better for short anastomotic strictures when conservative treatment is initiated ≤3 months after operation, although in our experience conservative management is rarely successful in these patients.[70]

Strictures not responding to conservative management or those with extensive disease at diagnosis require revision urethroplasty.[73] The surgeon must be prepared to harvest a local skin flap or buccal mucosa as there will likely be significant tissue loss at the site of the stricture. Attempts at repeated dilation or urethrotomy in these patients are usually not successful and should be discouraged because of the possibility of worsening the existing fibrosis.[74]

Urethral Diverticulum

Symptoms of urethral diverticula include weak urinary stream, post-void dribbling, UTI, and occasionally hematuria. The patient or caregiver may notice ballooning of the penile shaft during voiding (Fig. 60.6) or report the need to "milk" residual urine from the penile urethra. Diverticula occur more commonly in patients with onlay flaps, two-stage repairs, and with more proximal repairs.[75] This is in part due to lack of urethral reinforcement by a lack of corpus spongiosum tissue, which is absent or hypoplastic as part of the hypospadias complex. More often meatal stenosis or urethral stricture increases voiding pressures, causing dilation of the reconstructed urethra, resulting in a urethral diverticulum.[76] To achieve a successful repair the intraoperative approach must rule out distal urethral obstruction, with cystoscopy an important adjunct to define any uncertainties in the anatomy.

A small, localized saccular diverticulum can typically be excised and reduced in a longitudinal fashion, returning the urethral lumen to a uniform caliber. The more commonly encountered extensive megalourethra has traditionally been repaired by excision of redundant diverticular tissue, urethral closure, and multi-layered reinforcement before skin closure.[77] The redundant tissue is usually elastic, well vascularized, and lined with urothelium, making it an ideal candidate for repair of associated fistulas and distal strictures.[76] Various flap techniques have been employed to reconfigure redundant diverticular tissue for this purpose (Fig. 60.7).[78] Urethral plication in an extraurethral fashion is an alternative technique that does not violate the urethral plane.[79] As mentioned previously, interposition of a tunica vaginalis flap or dartos between the urethral closure and the skin is standard practice to reinforce the anastomosis and improve wound healing. Any repair beyond a simple excision should involve urine diversion for at least 7 days.

Meatal Complications

Characterizing meatal stenosis is difficult as definitions vary considerably across studies.[80] Technical aspects increasing the risk of stenosis include excessive extension of glans incisions and distal narrowing with glansplasty technique. Prolonged indwelling stent posturethroplasty may decrease the risk of stenosis development.[36] In the postoperative period the meatus should calibrate to a size no less than 8Fr. A narrowed meatus with symptoms of stranguria, deflected stream, poor uroflow, or urinary retention would suggest a clinically relevant stenosis that would warrant repair. Occasionally a stenotic meatus can be managed conservatively with meatal dilation with a sound and topical betamethasone cream.[81] Repeated dilation after hypospadias repair is not necessary as a routine practice to decrease rates of stenosis but may be indicated when the meatus appears small in the early postoperative period, and may be diagnostic of

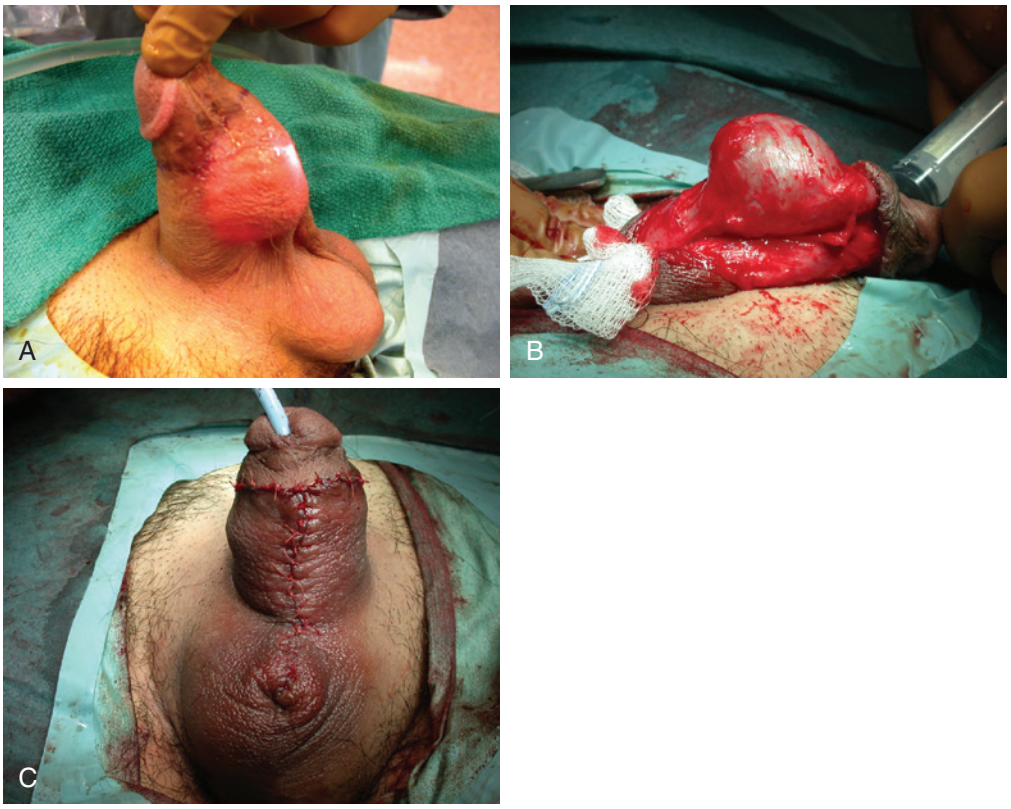


Figure 60.6 Urethral diverticulum in a pubertal boy after onlay hypospadias repair. A, The diverticulum highlighted with a cystoscope present within the defect. The defect is clearly seen in B after penile degloving. A satisfactory cosmetic result can be seen after closure of the diverticulum (C).

subclinical stenosis.[82] When the stenosis is refractory to dilation, a dorsal midline meatotomy can achieve patency in some cases.[83] Alternatively, an onlay utilizing a ventral penile flap can be successful in the absence of lichen sclerosis.[84] If these fail then revision glansplasty may be required and caution must be taken as there is often loss of glans tissue limiting the ability to achieve a cosmetic glans closure, necessitating a coronal meatus creation.

Meatal retrusion occurs when there is too much tension on the distal urethra or the glansplasty has broken down.[85] Meatal retrusion in part is due to improper surgical repair, resulting in an immobile urethra that retracts with penile growth, or a meatus that is noncompliant results in retrusion of the neourethra to its original position. The consequences of this complication are predominantly cosmetic rather than functional. However, if significant splaying or deflection of the stream occurs, revision of the meatus may be considered.[86]

Balanitis xerotica obilaterans (BXO) or lichen sclerosis is a chronic inflammatory dermatosis that can occur after hypospadias repair. Clinical presentation can vary and includes meatal stenosis or progression into the urethra, causing stricture. The initial course of treatment includes topical steroids (betamethasone 0.05%).[87] Unfortunately if conservative measures fail, surgical resection of all diseased tissue and reconstruction with buccal mucosa is required, often necessitating multiple reconstructive procedures.[88,89]

Persistent Chordee

Persistent chordee is an unfortunate complication of hypospadias repair that can have severe consequences from both a urinary and sexual function standpoint. Residual curvature may worsen as boys advance through puberty and undergo exponential penile growth.[90] Persistent or recurrent chordee occurs when the surgeon underestimates the intraoperative erection or fails to repair the curvature completely.[91] Improper technique can also result in extensive urethral scarring, which can tether the penis ventrally.

Residual chordee can be corrected but requires a systematic approach. Parents should be counseled that several procedures may be required. The first stage focuses on assessing the degree and source of chordee. We begin by assessing the ventral shaft skin and length of the urethra. Artificial erection after degloving will determine if the chordee is secondary to skin deficiency, urethral tethering, or corporal disproportion. If chordee persists after this procedure, elevation of the urethral plate down to the bulbar urethra if necessary has been shown to be another effective treatment (Fig. 60.8).[92] If bow-stringing of the urethra remains after mobilization, we divide the neourethra at the point of maximal curvature. If chordee remains, we proceed with corporoplasty designed to lengthen the ventrum of the penis with either dermal or tunica vaginalis grafting. We then move skin and dartos to provide a suitable bed for a subsequent free graft. The second stage of the repair involves placement of the buccal mucosa graft 12 months later, followed by urethroplasty at the third stage, again 12 months later. Shaft skin closure can be performed at that time but we often perform a Cecil modification during the third stage, which provides supple tissue for skin closure at the fourth stage.[69]

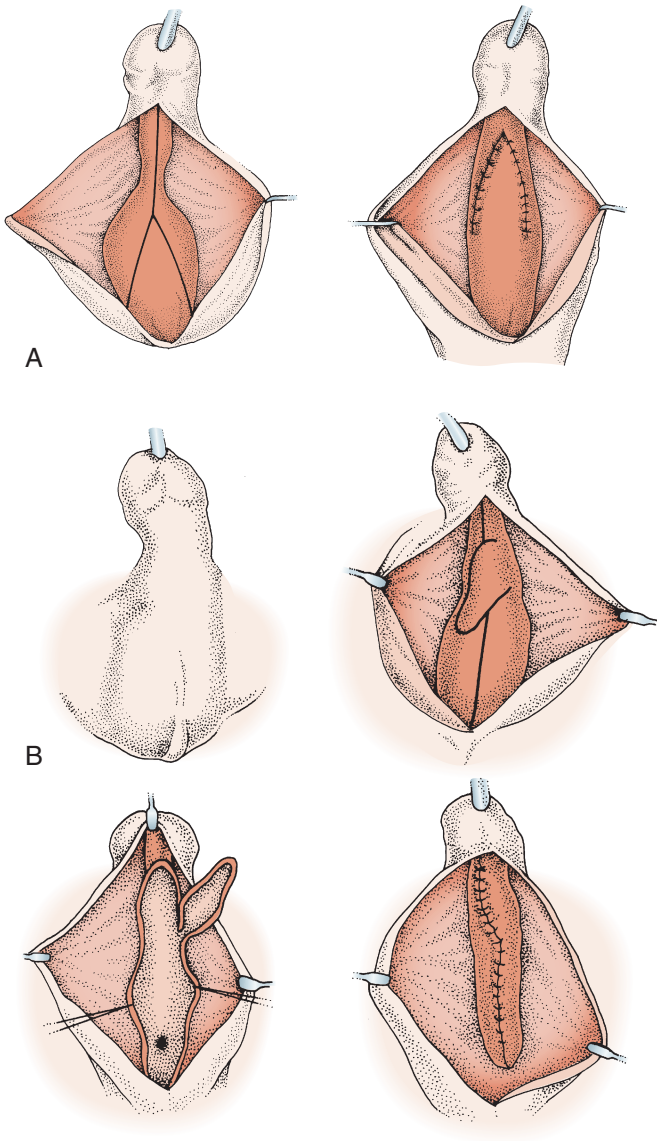


Figure 60.7 Use of diverticular tissue to correct distal stenosis. A, Repair of urethral diverticulum with distal stricture using Y-V plasty. B, Repair of urethral diverticulum with distal stricture using rotation flap.

Other Urethral Problems

If hair-bearing skin is used for the hypospadias repair, the patient may eventually experience protrusion from the meatus. This complication usually occurs after multiple-stage procedures or complex reoperations in which a paucity of non–hair-bearing skin is available but gets incorporated out of necessity. Hair in the urethral lumen occasionally acts as a nidus for stone formation or recurrent UTIs. Laser ablation has shown some initial success.[93,94] Stone debris can be endoscopically removed in the majority of cases. In severe cases with recurrent stones or UTIs, the affected area is excised and repaired with a buccal mucosa graft or a local penile shaft skin flap, if available.

Recurrent UTIs should prompt evaluation for urethral diverticulum or stricture. Occasionally, a voiding cystourethrogram demonstrates an enlarged prostatic utricle, which can promote urinary stasis, acting as a reservoir for bacteria. If no other source of infection can be found in these patients, consideration should be given to either excision or fulguration of the utricle.[25]

Psychological Consequences

In addition to surgical and functional concerns, studies in children, adults, and parents have identified psychological concerns with hypospadias repair. In a study of 6- to 10-year-old patients, behavior problems and poorer school performance was more likely in patients that underwent hypospadias repair when compared with age-matched controls.[95] In a series of adults who underwent hypospadias correction at an average age of 5 years, 38% had limited or no sexual experience (mean age, 27 years).[96] Overall, these patients tended to have fewer sexual partners and were older when they began sexual activity. Comparison of patient and parental expectations with those of the surgeon reveals a discrepancy that leads to an element of decisional regret.[97]

In general, adult patients with a history of hypospadias repair do not manifest major psychological problems. However, they tend to be less satisfied with penile appearance, have more inhibitions in seeking sexual contacts, as a result of embarrassment, and have a more negative genital appraisal. These patients tend to manifest more anxiety, hostility, and lower self-esteem, some of which may be ameliorated by operating at an earlier age.[98]

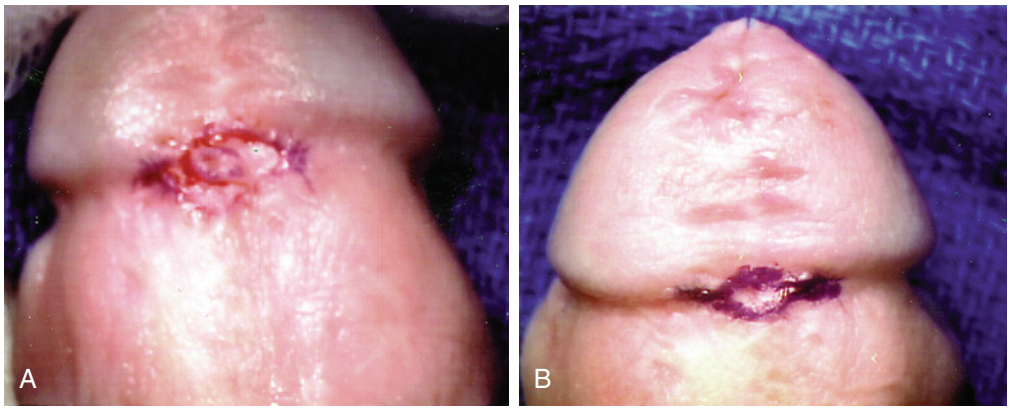


Figure 60.8 Fistula located at the coronal margin. Urehtral meatus was located within the distal glans and is without stenosis and the distal urethra calibrates normally to 8Fr.

Complex Hypospadias

Management of hypospadias complications depends on the complexity of the problem. Some boys can be managed with a single intervention, resulting in a cosmetically pleasing, functional outcome. With each successive procedure, however, the penis becomes more scarred and less tissue is available for reconstruction, and hence the complication rate increases with each successive repair.[99] A small percentage of patients undergo multiple unsuccessful repairs and are left with persistent, unresolved complications that result in significant morbidity that is often worse than the original congenital defect. To reiterate the importance of long-term follow-up and identification of these complications, Devine reasoned that "once complications have occurred in hypospadias repairs, the surgeon has a tendency to attempt small operations, hoping to convert failure with a minimum of effort. This generally makes matters worse. In these cases, extensive resection of scarring, major shifts of tissues and meticulous reconstruction will usually be found necessary to transform a difficult problem into a therapeutic success."[100] The approach to complex hypospadias reconstruction should include a full assessment of the number and degree of complications present, resection of all diseased tissue, and an aggressive surgical strategy in which the potential for success is maximized.

Salvage hypospadias for a focal issue (fistula, diverticulum) in the absence of chordee is ideally performed using a local skin flap that can be utilized as an onlay flap or for multi-layer vascular flaps.[99,101] We typically take this approach when redundant penile shaft skin is present from the original repair. When this is not the case, options are limited and tissue must be harvested from extra genital sites. Single stage repairs with full-thickness skin grafts had some initial success but significant complications such as graft shrinkage and stricture limited use of these grafts.[102] Bladder mucosal grafts have a reported overall complication rate of 40%, also limiting their use.[103] Complications related to the neomeatus have been the major drawback of bladder mucosal grafts, as prolapse can result in a cauliflower-type deformity in up to 38% of patients.[104,105]

Buccal mucosa is now the graft of choice in complex urethra reconstruction.[106–108] This tissue is ideally suited for urethral reconstruction because it is well adapted to contact with both fluid and air, readily neovascularizes, is hairless, minimally contracts, and causes little morbidity at the donor site. Because of its elasticity and good tensile strength, buccal mucosa can be used as an onlay graft, an inlay graft, or a tube graft and can be used to reconstruct the urethra in a single or multi-stage fashion. Long-term observation into puberty shows that the buccal graft is pliable and will not contract with age, an important aspect of management as we aim to avoid ventral chordee as a result of a tethered uretha.[109]

There are several key technical points when harvesting a buccal mucosa graft.[110] The graft should be outlined 10% larger than the needed surface area to allow for graft contraction as it incorporates. Closure of the donor site is controversial, and it remains unclear as to whether there is any benefit to such closure.[111,112] Although both are viable options for reconstruction, a labial graft appears to have fewer complications compared to the inner-cheek buccal mucosa.[113,114] For longer defects in complex cases or in older children, buccal mucosa can be used because it allows for a larger graft size. Alternatively, multiple sites can be combined to maximize tissue harvest. Strict attention to defatting and removing all nonmucosal tissue is important to allow neovascularization. The graft is then fenestrated with an 18G needle and placed in saline until the recipient site is prepared. Alternatively, one can prepare the recipient site first. A deep, long incision is made ventrally from the urethra through the glans to the site of the intended neomeatus.[115] The graft is then secured at multiple sites over the length of the graft, and quilting sutures are placed throughout the width of the graft to prevent hematoma formation, which can impede uptake. When performing a staged operation, the graft needs at least 6 months to heal before proceeding with urethroplasty and skin closure. We typically wait 12 months until to the next stage in reconstruction.

Conclusions

The surgical repair of hypospadias remains one of the biggest challenges in surgery. Although improvements in technique, instrumentation, and perioperative care have improved results, we still must deal with complications. By understanding the factors involved in failure of the repair, the surgeon can develop a logical and step-wise approach to repair to maximize the potential for success.

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Chapter 60 Questions

1. What is the most common complication of hypospadias repair?
   a. Urethral diverticulum
   b. Urethrocutaneous fistula
   c. Meatal stenosis
   d. Urethral stricture
   e. Urinary tract infection

2. Urethral diverticulum is more likely to occur with the following hypospadias repair:
   a. Tubularized incised plate (TIP)
   b. Thiersch Duplay
   c. Island onlay flap
   d. Meatal advancement glanduloplasty (MAGPI)
   e. Mathieu repair

3. What is the recommended age to perform a hypospadias repair?
   a. <3 months
   b. >18 years
   c. Just prior to puberty (<13 years)
   d. 6–12 months of age
   e. Once a patient enters puberty, i.e., exhibits Tanner V characteristics

4. Which of the following risk factors increase(s) the risk of developing a complication?
   a. Small glans size (<14 mm)
   b. Proximal hypospadias
   c. Undescended testis
   d. All of the above
   e. a and b only

5. Which of the following are key aspects of the surgical approach to prevent complications?
   a. Meticulous, atraumatic handling of tissues
   b. Subepithelial urethroplasty closure
   c. Utilization of fine, absorbable sutures for urethroplasty
   d. Multiple layers of well-vascularized closure
   e. All of the above

6. When ischemia results in eschar formation of shaft skin the following action should be taken:
   a. Complete resection of eschar
   b. Application of full-thickness skin graft to ischemic area
   c. Conservative management with application of petroleum jelly to allow healing by secondary intent
   d. Reapplication of dressing
   e. Sterile Betadine soaks until the eschar sloughs

7. When a complication is noted, the repair should be performed:
   a. Immediately regardless of the time since surgery
   b. At least 2 weeks from the initial procedure
   c. At least 6–12 months after the initial repair
   d. At the time the child enters puberty
   e. When the patient begins to toilet train

8. Urethrocutaneous fistula is most likely to present with the following:
   a. In conjunction with a urethral diverticulum
   b. With multiple urinary streams
   c. With a urinary traction infection
   d. With distal repairs only
   e. Much less frequently than a urethral stricture

9. The most definitive approach to a 2-cm urethral stricture after hypospadias repair includes:
   a. Direct visual internal urethrotomy alone
   b. Direct visual internal urethrotomy in conjunction with clean intermittent catheterization
   c. Urethral dilation with indwelling urethral catheter
   d. Revision of urethroplasty with local flaps or buccal mucosa
   e. Creation of a perineal urethrostomy

10. Ideal management of recurrent chordee and a tethered urethra in a patient with a history of a previous hypospadias repair includes:
    a. A staged approach in which the first stage addresses the chordee with corporal grafting with subsequent second stage urethral closure
    b. A single stage repair with dorsal plication
    c. A single stage repair with ventral fairy cuts and urethral mobilization
    d. A single stage repair with corporal grafting and closure
    e. A long tubularized incised plate repair with fairy cuts on the ventral corpora

Case Studies

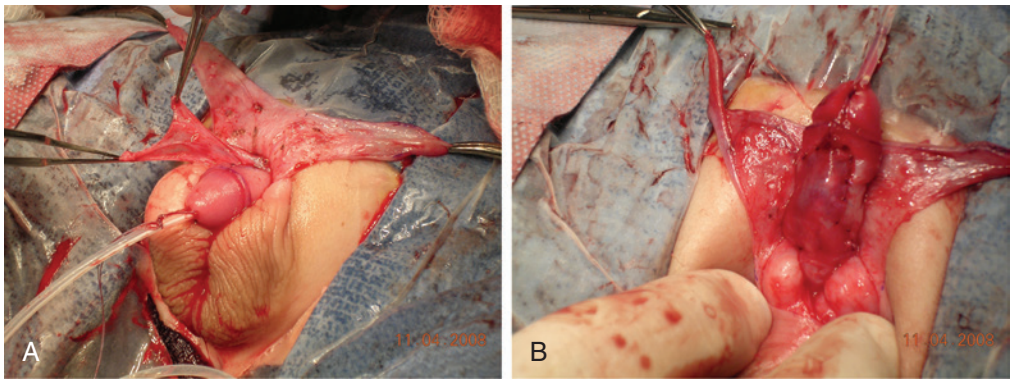
CASE 1

A 30-month-old boy underwent a subcoronal hypospadias repair via a Thiersch Duplay technique at the age of 8 months. He is now undergoing potty training and the parents report a recent history of two urinary streams, the second of which appears to be coming from the original site of the urethral meatus (Case Fig. 60.1).

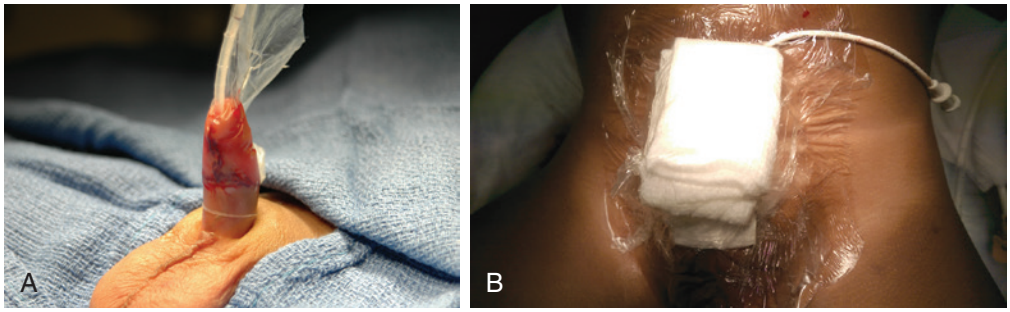
1. Which approach would you take to repair the hypospadias?
   a. Primary repair with excision of the fistula with multiple layer closure and urethral diversion
   b. Primary repair with excision of the fistula with multiple layer closure and no urethral diversion
   c. Placement of urethral catheter for 1 month and reassessment
   d. Redo hypospadias repair
   e. Placement of suprapubic tube for urinary diversion for 2 months for healing by secondary intent

Alternatively the fistula is located in a similar location but is more extensive (Case Fig. 60.2).

2. What treatment options would you offer at this time?
   a. Primary repair with excision of the fistula with multiple layer closure and urethral diversion
   b. Primary repair with excision of the fistula with multiple layer closure and no urethral diversion



Case Figure 60.1



Case Figure 60.2



Case Figure 60.3

c. Placement of urethral catheter for 1 month and reassessment
d. Redo hypospadias repair
e. Placement of suprapubic tube for urinary diversion for 2 months for healing by secondary intent

On postoperative day #1 after redo hypospadias repair the family calls with a complaint of blood in the diaper. They send a picture (Case Fig. 60.3).

3. What is the next best course of action?
   a. Remove the dressing and replace it with another compression dressing
   b. Return to the operating room for clot evacuation and replacement of dressing
   c. Observation
   d. Reinforce the dressing
   e. Admit to the hospital with full hematology workup

CASE 2

A 6-year-old boy presents to your office with concerns about penile pain and a urinary stream that is directed in a backward direction. He has a history of a previous proximal hypospadias repair at 1 year of age, performed in a single stage. You take him to the operating room and perform a cystoscopy, exam under anesthesia, and artificial erection after penile degloving. After penile degloving the urethral meatus is located at the proximal penile shaft with loss of the distal urethra and significant ventral curvature (>30 degrees) (Case Fig. 60.4).

1. What is your next step in management?
   a. Proceed with single stage hypospadias repair with urethral mobilization, ventral fairy cuts, and distal interposition tube
   b. Proceed with first stage of two-stage repair
   c. Multi-staged repair with the first step correcting ventral curvature with corporal grafting
   d. Dorsal plication in the ventral midline
   e. Dorsal plication via the Nesbit technique

Twelve months later you take the boy for his second-stage repair. At this point he has healed well with no residual penile curvature. The urethral meatus is located at the penoscrotal junction.



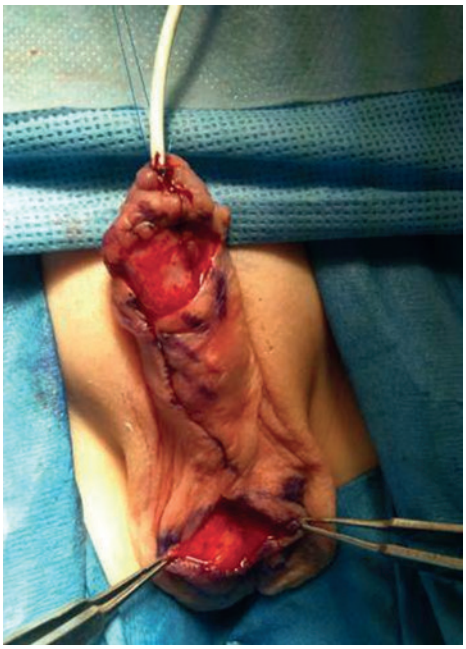
Case Figure 60.4

2. What is your approach?
   a. Harvest a flap from redundant penile shaft skin as an interposition tube to replace the distal urethra
   b. Harvest of a buccal mucosa graft as an interposition tube to replace the distal urethra in a single stage
   c. Harvest of buccal mucosa graft as a dorsal inlay with a planned third-stage procedure, at which time the distal urethroplasty is performed
   d. Utilization of a dermal graft as an interposition tube for the distal urethra replacement
   e. Leave the meatus at the penoscrotal junction until the patient enters puberty

At the time of the second stage procedure with urethroplasty you notice that there is a lack of ventral tissue for secondary coverage and skin closure.

When closing the buccal mucosa graft at the time of the third stage of the repair the lack of penile shaft skin prevents tension-free closure of the shaft skin. The picture below reveals an island of distal shaft skin that is unable to be closed at that time (Case Fig. 60.5).

3. What are your options at this point?
   a. Z-plasty technique to maximize skin coverage
   b. Full-thickness skin graft to replace defect
   c. Rotational scrotal flap to ventral shaft skin
   d. Cecil modification repair
   e. Split-thickness skin graft from the gluteal region to replace the defect



Case Figure 60.5

Answers

1. **b.** Urethrocutaneous fistula occurs in up to 10% of hypospadias repairs.
2. **c.** Island onlay flap is an approach that is more likely to result in a urethral diverticulum. It is also more likely to occur in a staged repair in which a long urethroplasty is performed.
3. **d.** Six to 12 months of age is the ideal age to perform a hypospadias repair based on the American Academy of Pediatrics' guidelines. This is before genital awareness occurs and at a stage when anesthetic risk is minimized.
4. **e.** The severity of hypospadias and smaller glans has been shown to result in higher rates of complications.
5. **e.** All of the above.
6. **c.** Conservative management with application of petroleum jelly will allow for healing via secondary intent, which rarely results in graft contraction.
7. **c.** At least 6–12 months after the initial repair. This allows the reconstructed tissue to heal, particularly the establishment of neovascularization, which maximizes success rates for further surgical intervention.
8. **b.** This occurs particularly around the age of potty training when the urinary stream is more likely to be observed.
9. **d.** A long stricture is less likely to respond to conservative management, and definitive repair involves revision of the urethra.
10. **a.** The association of a previous repair, persistent chordee >30 degrees is complex, and higher failure rates are observed when chordee and urethroplasty are addressed in the same procedure.

CASE 1

1. **b.** Primary repair by excision of the fistula tract with closure at the level of the urethra with multiple

layer closure with dartos and consideration of tunica vaginalis. Urinary diversion is optional but in a small fistula with an acceptable glans closure diversion can be omitted.

2. **d.** In this situation the fistula tract is close to the urethral meatus and there is limited surrounding tissue to allow multi-layer closure of the defect. The surgeon must calibrate the meatus to ensure patency and to ensure that no additional complications are present. Urethral diversion would be recommended in this situation given the location and increased risk of a secondary complication.
3. **c.** There is some evidence of bleeding but it is limited and is well controlled with the compression dressing. Removal of the dressing could potentially exacerbate the degree of bleeding. There is no indication for surgical exploration in the absence of uncontrollable bleeding in the immediate postoperative period. This is an acceptable amount of postoperative bleeding; workup for a bleeding diathesis is not necessary.

CASE 2

1. **c.** In the presence of severe curvature (>30 degrees) we find that corporoplasty is the best approach to correct curvature. The first step must ensure that the curvature has been corrected.
2. **c.** In our hands and in this particular setting of a complex redo hypospadias, buccal graft uptake is dependent upon a well-vascularized dartos layer that acts as a bed for receiving the graft. Simultaneous corporoplasty and buccal mucosa grafting increases failure rate, hence increasing the risk of recurrent ventral curvature.
3. **d.** In our hands we have had great success with the Cecil modification in the setting of ventral skin deficiency and redo hypospadias repair. By suturing the distal shaft defect into the mirror-image, diamond-shaped defect in the scrotum, neovascularization via the underlying dartos softens the shaft skin, allowing tension-free closure 12 months after the third stage. The shaft skin has already been maximized and additional Z-plasty incisions are not likely to increase skin coverage. Rotational scrotal flaps will place hair-bearing skin on the penile shaft, which is an unfavorable approach (Case Fig. 60.6).

   Closure of the penile defect into the scrotal defect with an interposed area of closed shaft skin (marked by hemostat in the picture) fosters growth of the dartos layer, which allows release and subsequent skin closure 12 months later.



Case Figure 60.6

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61 Complications of Surgery for Disorders of Sex Development

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CHAPTER OUTLINE

Overvirilization
Vaginal Agenesis and Vaginoplasty
Undervirilization and Gonadal Abnormalities
Conclusions
Chapter 61 Questions and Answers

KEY POINTS

1. The newborn with a disorder of sex development (DSD) must be evaluated for salt-wasting adrenal hyperplasia.
2. An assembled team of multidisciplinary experts should be assigned the task of educating and treating patients with DSD and their families.
3. Surgical procedures must be undertaken cautiously with knowledge of the accumulated and growing body of data, stressing functional and psychosexual adjustment outcomes.

Disorders of sex development (DSDs) can be defined by congenital conditions in which development of chromosomal, gonadal, or anatomic sex is atypical. These abnormalities comprise a myriad of disorders as illustrated in Table 61.1.[1] Debate has centered on the timing of genital surgery and on whether surgical treatment should be delayed until such time as the patient can be involved in the surgical decision-making process. Surgical procedures in patients with 46,XX DSD are most commonly encountered and have traditionally been performed early in life to avoid potential psychological stressors involved in rearing the child. The difficulty in the objective assessment of perceived psychological complications associated with genital ambiguity contributes to a lack of culturally adjusted, control-matched data that may help in solidifying the medical consensus in regard to management.

Discussion shall proceed under the assumption that patients in whom surgical treatment is deemed necessary have met and undergone evaluation and counseling with an assembled gender assignment team composed of chosen, experienced individuals in the fields of endocrinology, pediatric urology or surgery, psychology, social work, and genetics or dysmorphology. The purpose of such a team is to inform the legal guardians thoroughly of all available options including expectant management and the current state of and expected outcome in each area of reconstruction considered. Particular attention should also be given to discussion of psychosexual outcomes data or lack thereof. In patients who require surgical treatment, the surgeon has the responsibility to outline the surgical sequence and subsequent consequences from infancy to adulthood. Only surgeons with specific expertise in the care of these patients and specific training in the surgical treatment of DSDs should undertake these procedures.

For the purpose of discussion, it is useful to categorize patients in whom surgical treatment is necessary into three general groups:

1. Overvirilization
2. Vaginal agenesis
3. Undervirilization and gonadal abnormalities.

Each category is discussed in turn in this chapter.

Overvirilization

The most common cause of overvirilization is congenital adrenal hyperplasia (CAH), and 21-hydroxylase is responsible for 90% of cases. Surgical treatment for the clitoris should be considered only in cases of severe virilization (Prader III, IV, and V) and should be performed in conjunction, when appropriate, with repair of the common urogenital sinus. Parents now appear to be less inclined to choose surgical treatment for children with less severe clitoromegaly.[1] The only known function of the clitoris is in contribution to sexual pleasure.[2–3] Because orgasmic function and erectile sensation may be disturbed by clitoral surgery, the surgical procedure should be anatomically based to preserve erectile function and the innervation of the clitoris. Further delineation of neurovascular anatomy has allowed a more direct and conscious approach when clitoral surgery is necessary, to preserve the neural architecture important in the sensory aspect of sexual pleasure.[4–6]

Nerve density is lacking in the 12-o'clock position in contrast to the densely innervated 11- and 1-o'clock positions in respect to dorsal nerve distribution. In one report, cavernous nerves were noted to perforate the tunica albuginea

Table 61.1 Classification of Disorders of Sex Development

Sex Chromosome DSDs	46,XY DSDs	46,XX DSDs
A. 45,X (Turner's syndrome and variants)	A. Disorders of gonadal (testicular) development 1. Complete gonadal dysgenesis (Swyer's syndrome) 2. Partial gonadal dysgenesis 3. Gonadal regression 4. Ovotesticular DSDs	A. Disorders of gonadal (ovarian) development 1. Ovotesticular DSDs 2. Testicular DSDs (e.g., SRY+, dup 5OX9) 3. Gonadal dysgenesis
B. 47,XXY (Klinefelter's syndrome and variants)	B. Disorders in androgen synthesis or action 1. Androgen biosynthesis defect (e.g., 17-hydroxysteroid dehydrogenase deficiency, 5α-reductase deficiency, StAR mutations) 2. Defect in androgen action (e.g., CAIS, PAIS) 3. LH receptor defects (e.g., Leydig cell hypoplasia, aplasia) 4. Disorders of AMH and AMH receptor (persistent Müllerian duct syndrome)	B. Androgen excess 1. Fetal (e.g., 21-hydroxylase deficiency, 11-hydroxylase deficiency) 2. Fetoplacental (aromatase deficiency, POR) 3. Maternal (e.g., luteoma, exogenous)
C. 45,X/46,XY (mixed gonadal dysgenesis, ovotesticular DSD)	C. Other (e.g., severe hypospadias, cloacal exstrophy)	C. Other (e.g., cloacal exstrophy, vaginal atresia, MURCS, other syndromes)
D. 46,XX/46,XY (chimeric, ovotesticular DSDs)		

AMH, antiMüllerian hormone; CAIS, complete androgen insensitivity syndrome; DSDs, disorders of sex development; LH, luteinizing hormone; MURCS, Müllerian, renal, cervicothoracic somite abnormalities; PAIS, partial androgen insensitivity syndrome; POR, cytochrome P-450 oxidoreductase, StAR, steroidogenic acute regulatory protein

of the dorsal clitoral bodies near the crus.[6] The nerve distribution suggested by this study seems to correlate with reported areas of sensitivity and ease of orgasm as demonstrated by Schober and associates.[7] Despite evolving understanding of the neurovascular anatomy of the clitoris, it remains difficult to predict what types of surgical procedure will irrevocably alter clitoral sensation and sexual pleasure. Investigators have suggested that any type of clitoral surgery significantly alters sensation. Crouch and colleagues[8] reported that five of six women who had undergone feminizing genitoplasty had abnormal sensation results in response to temperature and vibration. One of the patients had undergone surgical treatment within 1 year of the study and conceivably had benefited from improved surgical techniques.[8] This finding demonstrates a typical situation in that it is often difficult to determine exactly what type of surgical procedure has been performed and whether newer techniques will impart preserved neurovascularity. Yang and colleagues reported on 51 patients who had undergone nerve-sparing ventral clitoroplasty (NSVC) performed by a single surgeon between 1996 and 2005 and concluded that the technique maintained neurovascular integrity of the glans clitoris. Limited data regarding sensitivity threshold were reported, likely secondary to a mean age of 6.8 years. Capillary refill was normal in 49 of 49 tested. Ten patients over 5 years of age were appropriate for sensitivity testing, which the authors interpreted as normal; however, there was no age-matched cohort without surgery with whom to compare. Two patients reportedly underwent preoperative and postoperative testing without significant differences in sensation thresholds.[9] In a related publication, Poppas et al. present findings from immunohistochemical staining of the reduced corporal tissue after NSVC by a single surgeon in 27 patients. They conclude that NSVC optimizes preservation of dorsal nerves.[10] It seems apparent that modern techniques more efficiently preserve neurovascular tissue, but without large series of patients that have undergone NSVC compared with age-matched controls and, perhaps more importantly, a number of patients old enough to undergo preoperative and postoperative sensory thresholds, it remains unclear how this effects psychosexual adjustment.

Two case reports in the literature noted that the preservation of dorsal and ventral neurovascular bundles while preserving the glans during reduction clitoroplasty imparted no difficulty in achieving orgasm or perceived decreased clitoral sensation. These surgical techniques were suggested as reproducible operations in children.[11–12] Thus, emphasis is on functional outcome rather than on strictly cosmetic appearance. Clinical trials in which success is judged solely on an acceptable aesthetic result are conspicuously insufficient and ignore the potential loss of psychosexual adjustment. It is also unreasonable to assume that preservation of neurovascular anatomic features will result in "normal" development and a gratifying sexual life. Investigators generally believe that surgical procedures performed for cosmetic reasons in the first year of life relieve parental distress and improve attachment between the child and the parents.[1]

The current recommendation is that surgical treatment, when necessary, be performed between the ages of 3 and 12 months. Evidence on the establishment of functional anatomy is inadequate to abandon the practice of early separation of the vagina and urethra.[1] The rationale for early reconstruction is based on guidelines on the timing of genital surgery from the American Academy of Pediatrics, the beneficial effects of estrogen on tissue in early infancy, anecdotally reported and experienced difficulty in performing feminizing surgery in adolescent and adult patients, and the avoidance of potential complications from the connection between the urinary tract and the peritoneum through

the fallopian tubes.[1] It is anticipated that surgical reconstruction in infancy will need to be refined at puberty.[1]

Although it is considered acceptable to undertake surgical correction of the common urogenital sinus at an early age, one must be aware and accepting of the likelihood of further surgical intervention in adolescence. Fourteen girls who had early surgical procedures were reassessed near adolescence and were found to have abundant fibrosis and scarring.[13] Another series reported the need for further surgical procedures in 43 of 44 similarly treated young girls with CAH to correct poor cosmesis or to correct introital stenosis.[14] It is currently unknown whether newer surgical techniques will lessen the need for surgical treatment later in life.

Several studies suggested that urogenital sinus mobilization, when possible, may decrease the risk of vaginal stenosis, especially if this procedure is performed early in life. These findings led to the further application and refinement of partial urogenital mobilization in feminizing surgery for the patient with CAH.[15–18] Encouraging early results based on position and caliber of vaginal introitus require longer follow-up to clarify further whether improved technique and early surgical treatment obviate the need for revisions in pubertal female patients. In a forthcoming publication, Stites and colleagues review toilet training success in 66 patients undergoing vaginoplasty for CAH-related urogenital sinus (UGS). Median age at time of surgery was 17 months. Techniques for vaginoplasty were flap vaginoplasty (41), total urogenital sinus mobilization (10), pull-through (nine), partial urogenital sinus mobilization (three), pull-through with partial mobilization of urogenital sinus (two), and cut-back (one). Sixty-four of 66 achieved continence without further surgery, though 11 required behavioral modification with or without pharmacotherapy and treatment for constipation. Two patients that had undergone total urogenital sinus mobilization (TUM) required urethral bulking to achieve continence. TUM requires dissection anterior to urethra and may extend proximal to pubourethral ligaments, presumably interfering with continence mechanism and may inherently impart a higher risk of incontinence.[19a] The current trend toward delayed operative intervention paralleled by the continued refinement of early surgical technique may produce enlightening outcomes data on psychological, physiologic, and anatomic function in these differently managed groups of patients.

Vaginal Agenesis and Vaginoplasty

An absent or inadequate vagina (with rare exceptions) requires a vaginoplasty performed in adolescence when the patient is psychologically motivated and a full partner in the procedure. No one technique has been universally successful; self-dilation, skin substitution, and bowel vaginoplasty each has specific advantages and disadvantages.

Considering a low vaginal confluence, the most popularly employed technique of vaginoplasty is skin substitution of the posterior vagina through an omega flap. The omega flap is a modification of the perineal skin flap proposed and developed by Fortunoff et al.[19b] Twenty-eight patients with a salt-losing form of CAH underwent posterior flap vaginoplasty between 1997 and 2001. Twenty-six of these patients had a low vaginal confluence. The age of these patients ranged from 5 months to 17 years, and follow-up was between 1 and 4 years. Nine patients had undergone previous surgical procedures but none had had prior vaginoplasty. None of the patients required further surgical treatment of vaginal stenosis or inadequate caliber, although two patients were undergoing continued vaginal dilation without reported difficulty.[20]

Jenak and colleagues[21] described the use of a narrow-based (omega) perineal skin flap to create a widened introitus. Four of the six patients had CAH, and follow-up ranged from 1 to 9 months. The mean vaginal calibration in four patients was 10.5 Hegar.[21] The initial cosmetic results noted in these two reports were encouraging, but long-term follow-up is needed to determine the functional capacity imparted in early versus late surgical vaginoplasty.

Another technique described, requiring 1.5–2 cm of urethral length, combines urogenital sinus mobilization with creation of urogenital sinus flaps. These urogenital sinus flaps can be posteromedially rotated to form a posterior vagina that is mucosa lined and thus obviate the need for a perineal skin flap. The group reported a mean follow-up of 2.5 years without vaginal stenosis or the need for vaginal dilation. The age range was 3 months to 13 years and CAH was present in seven of the 11 patients. Most of these procedures were accomplished with a perineal approach (eight of 11).[22] A major concern is whether the vagina will undergo stenosis or fibrosis that will increase the possibility of painful or unpleasant penetrative sexual intercourse in the future. Because assessment of successful results should incorporate both the feasibility and the quality of sexual intercourse, continuing methods of evaluating the quality of sexual life must be developed.

High vaginal confluence is generally considered to be >3 cm.[15] From a surgical standpoint, a high vaginal confluence indicates a position near or proximal to the urethral sphincter and the need for a vaginal pull-through procedure.[23–24] The likelihood of encountering this anatomic feature in a patient with CAH is 5%.[25] Vaginal pull-through requires separation of the vagina from the urethra and increases the probability of complications such as urethral stricture, urethrovaginal fistula, and urinary incontinence.

Hendren and Atala[23] reported the results of 16 female patients with high vaginal confluence and CAH who had undergone repair procedures using the described technique for pull-through with superior and inferior U-flaps and partially mobilized labia majora between 1962 and 1993. At the time of the report, nine of 16 women were adults and six of the nine were sexually active (five of six with heterosexual preference and one of six with bisexual orientation). One woman had given birth to a child by cesarean section, and at the time this was the first reported birth after a pull-through operation for high vaginal confluence.

In 1994, Donahoe and Gustafson[26] advocated a one-stage repair for patients at an early age and cited a high incidence of vaginal stenosis with the two-staged pull-through procedure. Three older patients aged 2, 3.2, and 9.2 years required the use of posterior buttock flaps. Three younger children aged 8, 8, and 12 months did not require

such flaps, and vaginoplasty was undertaken with the use of local tissue and a posterior, perineal skin flap. Follow-up at 6 weeks with endoscopic and anesthetic-aided examination and follow-up at 5 to 17 months indicated no fistulas and an adequate introital caliber. These investigators noted the importance of long-term follow-up to detect delayed vaginal stenosis. They also noted that injury to the urethra was of particular concern.[26]

A posterior approach as described by Pena and colleagues[27] included division of the rectum and creation of a diverting colostomy. Subsequently, Rink and associates[28] described a posterior prone approach in which the rectum was retracted and division avoided. Eight patients aged 6 months to 25 years underwent the procedure. Four had ambiguous genitalia and the other half had a pure urogenital sinus anomaly. Follow-up ranged from 6 months to 5 years and one patient was sexually active. These investigators noted greater mobility of tissue and no increased technical difficulty in the younger patients. One of the older patients required ongoing vaginal dilation for mild vaginal stenosis and a teenaged patient had an asymptomatic urethrovaginal fistula noted during cystoscopic examination.[28]

True vaginal agenesis is a rare condition consisting of primary amenorrhea and an intact hypothalamic-pituitary-gonadal axis in a genotypically and phenotypically normal female patient. Numerous techniques are described, dating as far back as 1817, when Dupuytren described creation of a pouch that could epithelialize without the use of a mold, to create a vagina in place of its absence or in place of a small vaginal dimple.[29] Technique has evolved with a common goal: creation of a functional vaginal vault in concordance with the desire of the patient, who accepts the ongoing need for self-dilation and commits to that regimen.

Nonsurgical dilation was first described by Frank in 1938.[30] Subsequently, the technique was described as successful and easier to perform using the patient's weight instead of digital pressure, especially when patients had no history of earlier surgical procedures and were motivated by an active sexual relationship.[30–34] Vaginal creation has been successful in 43% to 91% of patients by using the technique as described by Frank and further modified by Ingram.[35] In these patients, success is determined by the presence of a vagina that allows satisfactory penetrative sexual intercourse. Ingram's modification and initial report[35] involved 12 women with primary vaginal agenesis, and 62.5% of a total of 24 women (12 of whom had vaginal stenosis) reported comfortable sexual intercourse after 4 to 6 months of progressive dilation.

Surgical management of vaginal agenesis (Figs. 61.1 and 61.2) can be broken down into three categories:

1. Creation of space between bladder and rectum and use of mold and covering
2. Vulvovaginoplasty using skin flaps
3. Bowel segment vaginoplasty.

The primary advantage at the time of inception of the first-described use of a mold in a created perineal space was avoidance of the peritoneum. Different coverings have been used with variable success, including peritoneum, split-thickness skin grafts (STSG), bladder mucosa, amnion, and peritoneofascial flaps.[36–39]



Figure 61.1 Gross photograph of the introitus of a female patient with vaginal agenesis.



Figure 61.2 Magnetic resonance image of a female patient with complete vaginal agenesis. Note the dilated uterus with retained menstrual fluid.

Buccal mucosa was reported for use in vaginoplasty in 2003. Two different groups described the use of buccal mucosa free grafts of similar sizes for neovaginal creation in women with vaginal agenesis; the average age at time of operation in the two groups was 21.75 years. Both groups used similar technique in that a perineal space was created between the rectum and bladder, the graft size was increased by several small incisions ("meshing"), and grafts were placed within the neovaginal cavity such that the epithelial side was in contact with a subsequently placed vaginal mold or stent that remained in place for a period of time sufficient to aid in graft vascularization and epithelial proliferation. Follow-up was 15 to 18 months, at which time the authors had reported successful, regular intercourse and no occurrences of oral contracture or vaginal stenosis. Both groups suggested regular use of the vaginal mold or stent, with discontinuation of use only during times of regular intercourse, and both groups reported closure of the donor site with absorbable suture.[40,41] In 2014, Grimsby and Baker reviewed the literature and reported the senior author's experience with vaginal reconstruction and autologous buccal mucosa. Their series included 42 patients with CAH (n = 13), vaginal agenesis (n = 13), cloaca/UGS (n = 7), 46,XY (n = 6), cancer (n = 2), and Hircshsprung's disease (n = 1). In seven patients requiring total neovagina creation, two had had prior vaginoplasty. Immediate complications included urethral injury, recognized and repaired at time of surgery, and one dislodged vaginal stent that required another anesthetic for replacement of the stent. There were two patients that required revision: vaginal synechiae in one and vaginal foreshortening in the other. Five of the seven patients reported successful sexual activity, and two were not yet sexually active. Fourteen patients required distal vaginal augmentation, nine of whom had undergone primary repair of UGS. They describe mobilization of the UGS, urethroplasty, and autologous buccal mucosa used to bridge the gap between the vagina and perineum. No acute complications were reported. Three of 14 patients required revision for vaginal stenosis, and two of 14 developed oral contracture because of scarring at the donor site, with one of the two requiring further oral surgery. Donor sites were not reapproximated in any of the patients in this series. Buccal grafts were also used for successful treatment in cases of vaginal stenosis after primary vaginoplasty and some in whom vaginal stenosis repairs had failed. Stenotic areas were incised, and the tissue gaps were filled with buccal mucosa grafts. Three of 12 patients required revision for recurrence of stenosis, and one required oral surgery for oral contracture. With this publication, the authors illuminate the versatility of buccal mucosa free grafts for use in primary vaginoplasty and other types of vaginal reconstruction, while advising the need for long-term studies documenting outcomes in sexual function and health, reproduction, growth and growth characteristics of grafted epithelium, and direct comparison to other techniques.[42] Thirty-two women aged 17 to 39 years underwent surgical creation of vagina using a mold and STSG harvested from gluteus or thigh.[37] On postoperative day 7, the mold was removed to allow determination of STSG take, and it was then used continuously for 3 months. After time, it was possible to use the mold for 1 hour per week to avoid shrinkage. In judging the success of the procedure, these investigators used several criteria: STSG take, presence and degree of pseudomucinous metaplasia and associated sensitivity, vaginal dimensions and variation over time, and characteristics of sexual relationships. No regrafting was needed, and the rate of complete STSG take was 90.6%. Average vaginal dimensions were 10 cm in length and 4 cm in diameter. Twenty-seven of 32 (84.3%) women reported normal sexual activity with good sensitivity, and five did not engage in sexual intercourse. The rate of complications was 9.3% for partial take of STSG and 6.2% for partial vaginal stricture. One patient had total vaginal stricture. Success in outcome depended on mold management adherence or regular sexual activity.[37]

Long-term outcome in this type of reconstruction is directly related to the patient's motivation and willingness to comply with postoperative management and the desire for or presence of sexual intercourse.[43] An extensive retrospective review of 201 cases was reported in 1996.[44a] A modified Abbe-McIndoe procedure was performed in all cases with an average patient age of 20.5 years. In most cases, the impetus for performing reconstruction was the patient's desire to engage in sexual relationships. Follow-up was from 3 to 16 years, and the investigators reported low morbidity and high success rates. In this review, 156 women completed a sexual satisfaction questionnaire; 112 (71.8%) reported their sexual life as good or satisfactory, considering the presence of lubrication and the absence of dyspareunia, and some within this group noted insufficient vaginal lubrication. Reported complications were low and included graft site infection (5.5%), graft infection (4%), and rectal perforation (1%). The investigators recommended that surgical reconstruction be delayed until regular sexual intercourse is anticipated or desired by the patient.

The use of skin in vulvovaginoplasty has been described by several surgeons, with modern approaches derived from those described by Fliegner Jr.[44b], Fortunoff[19b], Williams[45a], and Donahoe and Hendren[45b]. Use of local skin in creation of a distal vagina in the case of a severely masculinized female patient with whom the decision has been made for reconstruction often requires more than a perineal skin flap. A proximal vaginal confluence increases the concern for incontinence and vaginal stenosis after reconstruction. Hendren and Donahoe[46a] described the creation of lateral and anterior walls of the distal vagina by using bilateral, medially rotated buttock flaps. Passerini-Glazel[46b] described the use of local skin for creation of distal vagina, advocated this technique for patients with proximal and distal vaginal confluence, and suggested that the procedure could be used at any age.

The use of musculocutaneous flaps is avoided in this patient population secondary to the considerable bulk of such flaps. The use of tissue expansion in the labia minora can create hairless, abundant, elastic, and well-vascularized flaps for creation of the distal vagina.[47] Donahoe and Gustafson[26] noted in 1994 that in patients presenting for vaginal exteriorization as part of a two-staged procedure, the use of bilateral rotated buttock flaps was necessary. In management of infants with a proximal vaginal confluence, no additional skin was needed for a posterior perineal-based flap and an anterior subphallic skin flap.[26] Based on the experience and comparison between the two techniques, the investigators recommended early, one-stage

reconstruction and emphasized the mobility of tissue and the use of labia minora and majora flaps for anterior and lateral introitus construction.[26]

Long-term follow-up in patients undergoing Passerini-Glazel feminizing genitoplasty demonstrated a significant difference in incidence of vaginal stenosis between two groups of patients. The first group, who had undergone the surgical procedure at a mean age of 2 years, was noted to have a 45% (10 of 22) incidence of vaginal stenosis. The incidence of vaginal stenosis was 25% (six of 24) in the group who underwent the procedure at a mean age of 14 years and who had a history of other surgical procedures performed at younger ages. The overall incidence of vaginal stenosis was noted to be 35%.[48]

When multiple approaches and the timing of surgical treatment are taken into consideration, the incidence of vaginal stenosis ranges from 11% to 94%. The decision to perform early reconstructive surgery should include the expectation for minor surgical procedures (i.e., introitoplasty) near the adolescent period.[13,14,23,49,50] Repair of vaginal stenosis should be undertaken at puberty when estrogen levels are high, to facilitate healing and to decrease the likelihood of recurrence.

Bowel segment vaginoplasty was initially described by Baldwin in 1904 and was subsequently avoided because of complications including several deaths.[29] The use of bowel to create a functional vagina has been associated with long-term complications unique to the use of a colonic segment such as the reported occurrence of diversion colitis associated with mucus discharge and bleeding.[51] Other complications or unwanted long-term associations include enteric segment prolapse, stenosis, and the long-term need for daily use of absorbent liners or douching for copious mucoid discharge.

Parsons and associates[52] reviewed 28 patients who had undergone colovaginoplasty and identified the following postoperative complications: introital stenosis (four), mucosal prolapse (four), partial small bowel obstruction (two), perineal hematoma (two), wound infection (two), and vaginal prolapse (one). The complication rate was 50%. The mean follow-up period was 6.2 years, and the patients in the review believed that adolescence was an appropriate time to undergo the procedure. Despite the high complication rate, long-term patency and cosmesis were not affected and 15 of 16 adult patients were sexually active.[52]

Hendren and Atala[53] reported on a large volume of patients who had undergone bowel segment vaginoplasty for various conditions. The most common complication was mucosal prolapse, occurring in 16 of 65 patients. The prolapse was easily repaired with a simple trimming, and the investigators believed that technical changes to avoid this minor complication would predispose the patient to more serious complications such as stenosis or bowel segment retraction. Recommendations from this report included early reconstruction to avoid the psychological ramifications of an absent vagina and daily douching with normal saline solution to prevent the accumulation of foul-smelling mucoid concretions.[53]

A published review of sigmoid vaginoplasty performed at a mean patient age of 16.8 years in 14 female patients with congenital vaginal agenesis indicated that the procedure provided a cosmetically suitable, self-lubricating vagina without the need for routine dilation, although daily irrigation and dilation were implemented for 8 weeks postoperatively. The psychosexual status of these patients was reported as acceptable, and no complaints of dyspareunia were reported. The patient population in the study was unique in that they had all presented at the inception of marriage arrangements. This finding indicates that the successful results were associated with older patients motivated, presumably, by the prospect of an active sexual life. Mean follow-up was 4.1 years.[54]

A review of the literature suggests that very few patients with CAH require the use of an enteric segment for construction of a functional vagina. In deciding whether to proceed with early as opposed to delayed reconstruction, one must weigh the potential psychological aspects of an absent vagina throughout childhood and early adolescence against the reported complications of vaginal stenosis and chronic discharge. Once again, evidence-based literature to help in establishing an algorithmic approach to decision making in this type of reconstruction is conspicuously lacking, and it is of utmost importance to consider each patient individually and to incorporate anatomic, physiologic, and psychosexual facets of personal development into the decision-making process. Family counseling and education with a multidisciplinary team approach are crucial.

Undervirilization and Gonadal Abnormalities

The undervirilized newborn with a DSD should be approached in the same manner as previously described, with a multidisciplinary approach in an experienced medical center. The historically described emergency status of the newborn with ambiguous genitalia has been challenged, and referral to an experienced center is always possible after the workup has ruled out true emergencies such as salt-wasting adrenal hyperplasia. 46,XY DSD is characterized by a spectrum of medical conditions including hypospadias, genetic syndromes, androgen receptor abnormalities, defects in androgen biosynthesis, and gonadal abnormalities. A specific diagnosis is identified in 50% of children with 46,XY DSD, in contrast to those children with 46,XX DSD.[1] Assuming that each patient has been carefully evaluated with full family participation and education, surgical treatment can proceed appropriately after consideration of factors including fertility, sexual function, degree of in utero exposure to androgens, psychosexuality, and culture.

In the case of a DSD associated with hypospadias, standard techniques for surgical repair such as chordee correction, urethral reconstruction, and the judicious use of testosterone supplementation apply.[1] An animal model of penile growth subsequent to testosterone stimulation indicated that the early use of synthetic androgen to achieve a more normal penis in childhood may ultimately result in the absence of further growth during puberty and result in a significantly smaller phallus.[55] Therefore, caution should be exercised when testosterone supplementation is considered.

The magnitude and complexity of phalloplasty in adulthood should be taken into account during the initial counseling period if successful gender assignment depends on this procedure.[56] At times this may affect the balance of

gender assignment. Patients must not be given unrealistic expectations about penile reconstruction, including the use of tissue engineering. No evidence indicates that prophylactic removal of asymptomatic discordant structures, such as a utriculus or Müllerian remnants, is required, although future symptoms may indicate surgical removal.

In a review including 57 patients over 20 years who were undergoing masculinizing genitoplasty, only two patients required excision of a utriculus. In this review, 77% of patients had severe penoscrotal hypospadias and 33% had perineal hypospadias.[57] Technique-specific, long-term outcome data are not sufficient to determine whether refinement in surgical technique will decrease the incidence of long-term complications. One-stage techniques may offer superior cosmetic and functional outcomes without the potential psychological trauma of repeated genital surgery.

Miller and Grant[58] reported on 19 patients in whom staged procedures had been performed for severe hypospadias. Only seven patients reported satisfactory ejaculation, and 15 reported satisfactory erection and orgasm. A questionnaire completed by 22 men aged 18 to 26 years in whom surgical treatment had been performed in childhood for hypospadias (severe, 11) identified penile size as a cause of dissatisfaction.[59] Age-matched controls showed no significant differences in sexual behavior, and a slightly higher rate of dissatisfaction was reported in the surgical group (40.9% vs 34.2%).

Using the described modern surgical techniques involving inner preputial skin, Chertin and colleagues[57] performed masculinizing genitoplasty in 39 patients at a median age of 1.8 years. With a median follow-up of 6 years, 10 patients required further surgical procedures for urethral breakdown (three), urethrocutaneous fistula (five), and excision of utriculus (two).

Lam and associates[60] reported on the outcome in 27 male patients who had undergone two-stage repair of hypospadias in infancy for congenitally located meatus at midshaft or more proximally. Five patients had a DSD and hypospadias. Additional surgical treatment had been necessary in five patients for excision of diverticulum, in three patients for fistula, and in four with minor urethral strictures. Forty percent of patients experienced spraying of the urinary stream but were able to stand and urinate. Nine of 20 patients who were able to ejaculate reported the need to "milk" the ejaculate. All patients reported satisfaction with genitourinary function, and 23 of 27 were happy with their penile appearance.[60]

When considering masculinizing genitoplasty for the patient with a DSD, one must be mindful of potential complications of Müllerian remnants and dysgenetic gonadal tissue. Utricular manifestations may include chronic urinary dribbling, recurrent urinary tract infection, and multiple failed attempts at hypospadias repair. Desantel and colleagues[61] found a high risk of infertility in patients undergoing surgical treatment for symptomatic utricles. This condition was thought to be either secondary to abnormal anatomic insertion of ejaculatory ducts or vas deferens or caused by operative injury.

The severity of hypospadias or micropenis should not be considered when one determines the sex of rearing in the patient without an androgen receptor defect. Current data do not support the amputation of sexually sensitive and functional but small male phallic structures.[56,62,63] Another review of patients with micropenis noted that either male or female gender assignment was possible, and no patients sought gender reassignment. The investigators noted a higher complication rate in feminizing surgery and a higher rate of dissatisfaction with external genital appearance and concluded that male gender assignment was preferable.[64]

In management of the patient with a DSD, removal of gender-discordant structures is generally directed by symptoms or risk of malignant disease. Specifically, varying degrees of gonadal dysgenesis may be present and may necessitate surveillance or removal of this tissue. This situation is encountered in the patient with a DSD and Y chromosomal material. Several gene mutations that have been identified and documented are associated with DSDs and a propensity toward gonadal malignant disease.[1,65]

Historically, gonadal biopsy and excision were performed using laparotomy. More recent trends support the use of laparoscopy for diagnosis, biopsy, and excision of aberrant or discordant structures.[66–69] Standard laparoscopic techniques apply, and three-port placement is sufficient for surgical procedures in the pelvis. Bladder drainage increases visualization and reduces the chance of injury during laparoscopic pelvic surgical procedures, particularly in the patient weighing <15 kg.

The testes in patients with complete androgen insensitivity syndrome and in those with partial androgen insensitivity syndrome who are raised as girls should be removed to prevent malignant disease in adulthood.[1] The availability of estrogen replacement therapy allows for the option of early removal of testes at the time of diagnosis. This approach also takes care of the associated risks of hernia, psychological problems with the presence of testes, and malignancy. Parental choice allows deferment of treatment until adolescence, because the earliest reported malignancy in complete androgen insensitivity syndrome occurred at 14 years of age.[1]

The streak gonad in a patient with mixed gonadal dysgenesis who is raised as a boy should be removed laparoscopically (or by laparotomy) in early childhood.[1] Bilateral gonadectomy is performed in early childhood in girls (bilateral streak gonads) with gonadal dysgenesis and Y chromosome material. In patients with androgen biosynthetic defects who are raised as girls, gonadectomy should be undertaken before puberty. A scrotal testis in patients with gonadal dysgenesis is at risk for malignant disease.

Current recommendations are testicular biopsy at puberty to seek signs of the premalignant lesion termed *carcinoma in situ* or *undifferentiated intratubular germ cell neoplasia*. If results of the biopsy are positive, the option is sperm banking before treatment with local low-dose radiation therapy, which is curative.[1] Surgical management of DSDs should also consider options that will facilitate the chances of fertility. In patients with a symptomatic utriculus, removal is best undertaken laparoscopically to increase the chance of preserving continuity of the vasa deferentia.

Patients with bilateral ovotestes are potentially fertile from functional ovarian tissue.[1] Separation of ovarian and testicular tissue can be technically difficult and should be undertaken, if possible, in early life. Four-fifths of ovotestes will demonstrate tissue that is adjacent and clearly demarcated in an end-to-end fashion.[70]

Conclusions

Growing numbers of specialty trained and experienced physicians, advocacy and support groups, and well-informed patients and families herald a future for the child with a DSD that is free of stigma and abounds with the opportunity for a life of choice. It is quite clear that technical advances have decreased the number of surgical procedures and complications associated with DSDs. The possibility of delaying surgical treatment when it is not immediately necessary will perhaps provide the community with a patient population that is older and more involved in the treatment decision-making process. This would provide the community with a control population to illuminate the areas of neuroanatomic and psychosexual functioning further. For example, we may learn that, regardless of age at surgical reconstruction, the patient with a DSD is more likely to have difficulty in adjusting.

Education and further clinical trials undoubtedly will clarify this issue in the future, particularly with emphasis on all facets of outcome, including an extrapolation of the previously held notion that successful outcome was based on appearance and the ability to engage in conventional sexual intercourse. Expanding models of sexuality will aid in defining a reproducible measure of sexual function and psychological well-being. Critical factors should remain well within the foreground during discussions with family and health-care providers: preservation of fertility, preservation of sexually sensitive tissue, measures and metrics for determining successful outcome, cultural and societal factors, and the time-honored, sage admonition – *primum non nocere*.

References

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Chapter 61 Questions

1. You are asked to see a newborn with atypical genitalia (Case Fig. 61.1). The term infant was born by vaginal delivery and has good Apgar scores. The infant is ready to be discharged from the hospital. What is the best diagnostic study?
   a. MRI
   b. Sonogram
   c. Genitogram
   d. CT scan
   e. Laparoscopy

2. After sending a sample for a chromosome analysis, what is the most important test?
   a. Complete blood cell (CBC) count
   b. Serum testosterone
   c. 17-OH progesterone
   d. Electrolytes
   e. Androstenedione

3. A voiding cystourethrogram (VCUG) is shown in Case Fig. 61.2. What do the *black arrows* denote?
   a. Utricle
   b. Fistula
   c. Rectum
   d. Cervix
   e. Introitus

4. What does the *white arrow* in Case Fig. 61.2 denote?
   a. A high confluence
   b. A low to middle confluence
   c. The vagina
   d. The urethra
   e. The rectum

5. After surgical repair, what likely outcome should the family be counseled about?
   a. The need for examination and revision when the child is a teenager
   b. Loss of sexual function
   c. Gender dysphoria
   d. Infertility
   e. Cancer

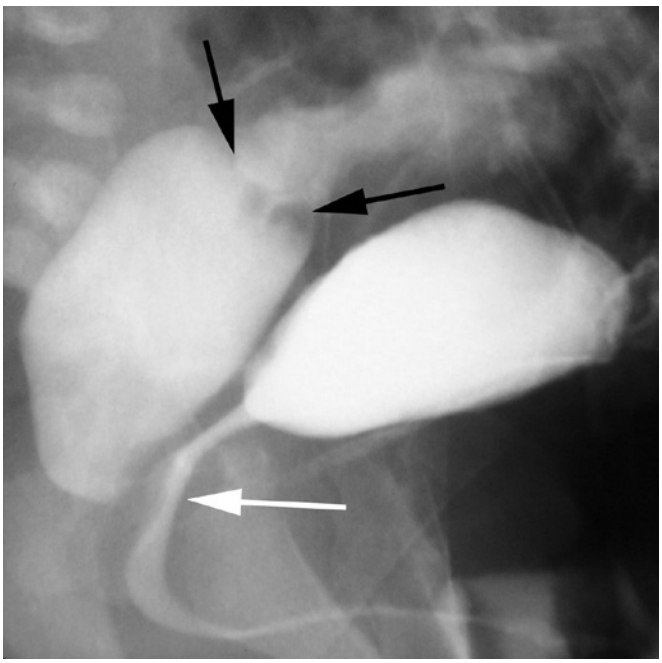
6. A 12-year-girl complains of cyclic abdominal pain lasting for 5 days and returning each month. Physical examination reveals a pelvic mass and no vaginal opening but a normal introitus (Case Fig. 61.3). What is the best test to determine the diagnosis?
   a. MRI
   b. Sonogram
   c. Genitogram
   d. Serum testosterone
   e. Serum levels of FSH and LH

7. An MRI of the abdomen and pelvis is obtained (Case Fig. 61.4). What organ is absent in the MRI study?
   a. Kidney
   b. Uterus
   c. Ovary
   d. Vagina
   e. Clitoris

8. A patient with similar findings of vaginal agenesis but no uterus has complete androgen insensitivity syndrome. What is this patient at risk for?
   a. Gender dysphoria
   b. Gonadoblastoma
   c. Wilms' tumor
   d. Cervical cancer
   e. Aneurysm



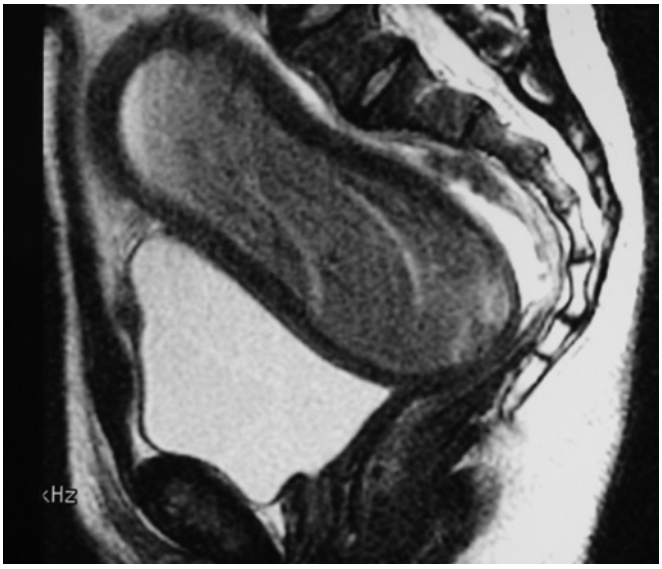
Case Figure 61.1



Case Figure 61.2



Case Figure 61.3



Case Figure 61.4

9. A 6-month-old, XY boy with severe hypospadias responds to testosterone stimulation with phallic growth. At the time of surgery, it is difficult to pass a tube into the bladder. What is the most likely reason?
   a. Urethral stenosis
   b. A utricle
   c. Rectal fistula
   d. High bladder neck
   e. Inaccurate diagnosis

10. Patients undergoing repair of severe hypospadias are at risk for what condition?
    a. Fistula
    b. Urethral diverticulum
    c. Urethral stenosis
    d. Chordee
    e. All the above

Case Studies

CASE 1

1. A newborn presents with atypical genitalia shown in Case Fig. 61.1. Gonads are not palpable. The initial most important diagnostic test is:
   a. Karyotype
   b. Pelvic sonogram
   c. Electrolytes
   d. 17-OH progesterone

2. The diagnosis of 21-hydroxylase deficiency is made in the same patient. What is the next step in deciding surgical reconstruction?
   a. MRI
   b. Genitogram
   c. Laparoscopy
   d. Exam under anesthesia

3. The genitogram shows a high urogenital sinus, and the patient undergoes a partial urogenital sinus mobilization with nerve-sparing clitoroplasty. What is the most common complication after surgery?
   a. Urinary tract infection
   b. Unsatisfactory sexual function
   c. Distal vaginal stenosis
   d. Lack of orgasm

CASE 2

A baby with Prader V congenital adrenal hyperplasia (CAH) and high urogenital sinus undergoes a total urogenital mobilization and reduction clitoroplasty (Case Fig. 61.2).

1. What are possible complications from injuring the dorsal nerve of the clitoris during genitoplasty?
   a. Decreased glans sensation
   b. Decreased erectile dysfunction
   c. Decreased sexual arousal
   d. All the above

2. What is the best use of excess tissue from the common urogenital sinus?
   a. Anterior vaginal wall reconstruction
   b. Posterior vaginal wall reconstruction
   c. Labia majora reconstruction
   d. Labia minora reconstruction

3. Reduction of the glans clitoris to maximize sensation should be performed on the:
   a. Ventral aspect
   b. Dorsal aspect
   c. Lateral aspect
   d. At the coronal glans margin

Answers

1. **b.** The most practical choice is a sonogram. In the newborn period, ultrasound can document the presence of a uterus in patients with congenital adrenal

hyperplasia, which is the most common diagnosis for patients with disorders of sex development. The other studies also can do this but are invasive or require anesthesia or irradiation.
2. **d.** For patients with possible congenital adrenal hyperplasia, it is critical to rule out a salt-losing form, which can be life threatening.
3. **d.** The black arrows point to the top of the vagina or the cervix (which is seen as an impression) in this patient with congenital adrenal hyperplasia.
4. **b.** The white arrow denotes the confluence of the urethra and vagina. If the confluence were close to the bladder neck, it would be considered high. In this case, it is middle to low, which has ramifications for the type of surgery.
5. **a.** Patients undergoing surgery for congenital adrenal hyperplasia often require at least an examination under anesthesia as they go through puberty to rule out vaginal stenosis at the introitus.
6. **a.** The diagnosis of vaginal agenesis is best made by MRI.
7. **d**. The enlarged uterus is clearly seen on MRI along with absence of the vaginal canal, which is consistent with vaginal agenesis. Patients with vaginal agenesis also may have an absent kidney (Mayer-Rokitansky-Kuster-Hauser [MRKH] syndrome), but the MRI cut does not include the area of the kidneys for evaluation.
8. **b**. The patient with complete androgen insensitivity syndrome is at risk for cancer in the intraabdominal gonads, which should be removed at or before puberty.
9. **b.** A prostatic utricle is more likely in patients with severe hypospadias.
10. **e.** Patients undergoing repair of severe hypospadias are at risk for all of the conditions and require long-term follow-up.

CASE 1

1. **c.** In a newborn with atypical genitalia and nonpalpable gonads the most common diagnosis is congenital adrenal hyperplasia. The workup includes all of the answers but initially it is important to check electrolytes to rule out salt wasting, thereby avoiding an adrenal crisis.
2. **b.** A genitogram will determine the level of confluence of the urethra and vagina and the length of the common urogenital channel. This will allow a determination of whether this is a high versus low confluence, thereby helping to plan both the type and length of reconstruction.
3. **c.** The most common complication after repair of a high urogenital sinus is distal vaginal stenosis. Therefore these patients need a careful exam before puberty and counseling that an additional procedure may be required to correct the distal stenosis at that time.

CASE 2

1. **d.** All the above. The dorsal nerve of the clitoris innervates the glans and skin of the clitoris affecting all aspects of sexual function.
2. **a.** Excess common urogenital sinus tissue is best used for reconstruction of the anterior vaginal wall by splitting sinus on the dorsal aspect and flipping the excess sinus tissue 180 degrees to anastomose to the anterior vaginal wall.
3. **a.** The dorsal nerve of the clitoris enters the glans clitoris on the dorsal aspect with the sparsest innervation being on the ventral aspect of the glans; hence if reduction clitoroplasty is indicated it should be performed on ventral aspect.

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62 Complications of Pediatric Urinary Diversions and Bladder Augmentation

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CHAPTER OUTLINE

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Pregnancy Following Bladder Augmentation and Urinary Diversion
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KEY POINTS

1. In infants (<1 year of age) with obstruction of the urinary tract, long term usage of a percutaneous nephrostomy or suprapubic tube is associated with a 40% complication rate. If temporary drainage for over six months is required, the surgical creation of tubeless urinary diversion via either a cutaneous pyelostomy, ureterostomy or vesicostomy are preferred.
2. The incidence of bladder cancer is increased in all children with a congenitally abnormal bladder with a incidence of approximately 1% per decade of life. This risk is not significantly increased in patients undergoing a ileal or colonic bladder augmentation, approximately 1.5% per decade post augmentation.
3. Spontaneous perforation of an augmented bladder has reported mortality incidence of 25% and most often occurs due to patient non-compliance with intermittent catheterization.
4. The use of urinary conduits is associated with 80% incidence of new onset of renal scarring during a 20 year observation period. The risk of renal scarring is directly related to the development of either stomal stenosis or ureteroenteric stenosis.
5. The use of a tunneled enteric anastomosis has twice the risk of developing a ureteroenteric stricture (1% per ureter per year) compared to a flush ureteral enteric anastomosis (0.5 % per ureter per year).
6. The use of high volume (>240 mL) daily bladder irrigations has been documented to decrease the risk of bladder calculi formation following a enteric bladder augmentation by 5 fold.
7. In patients with ≥2 recurrent bladder calculi following a bladder augmentation 30% of patients will develop a third stone within five year observation study period. Metabolic abnormalities will be found in 90% of these patients however, neither successful treatment of the metabolic anomaly nor, the use of indwelling mucolytic agents have been found to decrease this risk.
8. Stomal revisions of continent catheterizable limbs are two times more frequent following formation of a Monti catheterizable stoma compared to a appendicovesicostomy.
9. Approximately 10% of patients where the ileum, or ileal cecal junction was used for urologic reconstruction purposes will develop low B_{12} levels by the fifteenth post-operative year.

The Goals of Congenital Urologic Diversions and Urinary Reconstruction

The goals of congenital urologic reconstructive surgery are fourfold: preservation of life, preservation of renal function, creation or preservation of urinary continence, and creation or preservation of sexual function. There is one proviso in the clinical application of these four goals: At no time should one of the lesser goals trump those that go before it.

Complications Following Temporizing Urinary Diversions of Infancy and Childhood

CUTANEOUS PYELOSTOMY, URETEROSTOMY, AND NONCONTINENT VESICOSTOMY

Unlike adults where prolonged drainage of the urinary tract system can be safely performed by percutaneous nephrostomy or suprapubic cystostomy tubes, attempted management of infants by continued percutaneous access is associated with a 40% incidence of complications.[1,2] Specifically, frequent tube dislodgment, urinoma, or obstruction will occur in 15%; infectious complications, pyelonephritis, cystitis or urosepsis in 15%; and bleeding complications, retroperitoneal hemorrhage, or chronic anemia with the need for transfusion due to low-volume but persistent blood loss in 10%.[1,2] Due to the frequency of these complications the surgeon should consider the use of tubeless diversions, such as cutaneous pyelostomies, ureterostomies, or vesicostomy, in any infant where definitive reconstruction is to be delayed for greater than 6 months. Classically, cutaneous pyelostomy or ureterostomies are performed in infants presenting with an infected obstructive ureter(s), bladder hypoplasia/agenesis, or as a palliative procedure in infants with large nonresectable pelvic tumors. Cutaneous pelvic or ureteral stenosis will occur as a postoperative complication in 10–15% of these cases and recurrent pyelonephritis in 20%.[3,4] When pyelonephritis does occur it is usually associated with either a cutaneous stenosis or a poorly functioning kidney associated with urinary stasis. In these latter patients, resolution of the recurrent infections is best treated by nephrectomy.[3,4]

A cutaneous noncontinent vesicostomy is a temporary urinary diversion used to decompress the bladder and upper tracts in the presence of bladder outlet obstruction. It is classically indicated for the following conditions: (1) in infants with posterior urethral valves where the urethra is too small for endoscopic instruments; (2) in patients with neurogenic bladders, cloacal anomalies, or imperforate anus where urethral catheterization is difficult; (3) in patients with common cloacal or imperforate anus where urethral–rectal fistulas have resulted in metabolic abnormalities or repeated urinary tract infections (UTIs); and (4) in infants where parenteral noncompliance with medical directives is a concern.[5–8] Revision of the vesicostomy due to either stenosis or prolapse will be necessary for 10% of infants.[3,5,7–9] Although this is an excellent form of temporary urinary diversion in neonates, its use becomes more problematic after 3 years of age. Specifically, with maturation, the bladder changes from predominantly an intraabdominal to a pelvic organ. The relative change in position will result in the need to significantly mobilize the bladder to reach the skin level and be associated with increased tension on the vesicocutaneous anastomosis resulting in a significantly increased risk of vesicocutaneous stricture formation in the older child or adult. As the child matures attempts to cover the stoma with diapers, protective clothing, or a collection bag become increasingly problematic with the stoma location usually being cephalad to the areas covered by protective clothing. The stoma is also in a highly mobile area, associated with multiple skin folds, which significantly hinders the patient's ability to maintain a stomal collection bag. The inability to successfully contain the urine results in problems with skin irritation, breakdown, need for frequent clothing changes, and a decrease in the societal acceptance of the malodorous patient. Take down of a cutaneous vesicostomy is therefore commonly pursued between 1 and 2 years of age.[8]

Complications Following Definitive Urologic Reconstruction in Childhood

Management of patients with spina bifida and bladder exstrophy has played a major role in the development of reconstructive urology. Children suffering from these anomalies were initially at risk for chronic UTIs, pyelonephritis, end-stage renal failure, and death.[10–13] If they did survive to adulthood, they faced the social stigma and psychological trauma associated with chronic urinary incontinence.[14,15] Physicians empathetic to these children's dilemma began to seek ways to surgically intervene in the 19th century, usually with abysmal results.[10,11] A significant technical leap forward occurred in the 1950s with the concurrent development of broad-spectrum antibiotics and the ileal conduit.[16] For approximately 3 decades the use of urinary conduits (either ileal or colonic) and ureterosigmoidostomy reigned supreme. During the 20–30 years of their heyday, physicians slowly came to realize their association with metabolic derangements, renal lithiasis, chronic pyelonephritis, advancing renal insufficiency, and, in the case of ureterosigmoidostomy, malignancy.[17–26] The death knell for these procedures as the predominant surgical reconstructive methods for congenital urologic anomalies occurred in the late 1970s when multiple publications revealed the operations were associated with either a significant risk for renal deterioration and/or malignancy and recommended these operations be abandoned in children.[17–20]

Reconstructive efforts were subsequently refocused in the direction of bladder augmentation and continent urinary reservoirs. It was believed that the use of bladder augmentations or urinary reservoirs – procedures that are liberated from the fecal, urinary slurry and relatively free from the risk of stomal stenosis, parastomal hernias, and ureteroenteric strictures – would be associated with a significant decrease in morbidity and mortality.

Currently, bladder augmentations or continent urinary reservoirs are reserved for use in patients with either a congenitally or surgically absent bladder, sustained detrusor overactivity, i.e., detrusor pressures, ≥40 cm H_20, or poor detrusor compliance, i.e., end fill detrusor volume/end fill detrusor pressures of <20 mL/cm of H_20. Patients with sustained detrusor overactivity or poor detrusor compliance are already associated with or clinically at risk for upper tract renal deterioration and urinary incontinence. They are considered for this procedure only after they have been proven to be recalcitrant to intermittent catheterization and anticholinergic medications and after failing or refusing intravesical injections of onabotulinumtoxin A.[5]

Unlike urinary diversion for the management of malignancy, the success and complications of urinary reconstruction in children are measured by long-term outcomes.[15,27–31] Currently, the lifetime risk for needing an additional surgical intervention to treat complications arising from a bladder augmentation, continent urinary reservoir, or urinary conduit in childhood is >50%.[28,31,32] This incidence does vary from study to study based on the length of follow-up, the type of operation performed, the use of concurrent bladder outlet obstructive procedures, the presence of continent abdominal stomas, and the patient's ability to comply with medical directives. In this regard, this chapter will focus not on the immediate postoperative complications but rather on the long-term consequences found upon decades of follow-up.

Lethal Complications Following Urologic Reconstruction in Childhood

NEOPLASIA

The development of a malignant tumor within a urinary reservoir or augmented bladder is based on the type of bowel used, the length of time from surgery, the concurrent use of immunosuppressives, and the etiology for primary bladder dysfunction.[26,29] It is noteworthy that the overall risk for development of a bladder malignancy is increased in all patients with a primary congenital bladder dysfunction.[26,29] The incidence of bladder cancer development within this population is approximately 1% per decade.[26,29] This risk is not significantly increased if these patients undergo an ileal or a colonic bladder augmentation; reported incidence following these procedures is approximately 1.5% per decade.[26,29] This risk is, however, approximately tripled to 2.8% per decade for patients undergoing a gastric augment and is increased approximately fivefold, i.e., 5% per decade, following a ureterosigmoidostomy.[25,26,33,34] Two specific patient populations appear to be at an increased risk for tumor development following a bladder augmentation; specifically, patients who have undergone a gastric augment and patients with an augmentation who are on immunosuppressives.[26,33,34] Both of these patient populations appear to have between a two- and threefold increased risk for cancer development compared to patients with a primary congenital bladder dysfunction.[26,29,33]

The question that arises is, should patients with congenital bladder dysfunction treated by bladder augmentation be routinely screened by annual endoscopy and cytology? We currently do not believe data exist that can support this recommendation.[28] Specifically, the World Health Organization recommends annual cancer screening be performed when the four following criteria are met: (1) cancer has a high prevalence within a well-defined patient population; (2) cancer routinely presents at a low treatable stage; (3) screening tests are available that are safe, inexpensive, reliable, and reproducible with high specificity and sensitivity; and (4) the screening test must allow the cancer to be diagnosed at a low treatable stage and result in an improved patient prognosis.[26,29,30]

Currently, epidemiologic and pathologic findings reveal tumors arising within a congenitally dysfunctional bladder cannot meet these criteria. Specifically, 5–7.5% of patients with congenital bladder dysfunction with or without an augment will develop a bladder cancer by the sixth decade of life, a 1–1.5% risk of malignancy per decade. Approximately 80% of these patients will present with locally advanced disease or nodal metastasis at the time of diagnosis, with a cancer-specific mortality of 80% at 18 months following the diagnosis.[26,29,30]

Pathologic evaluations inevitably reveal unique morphologic, immunohistochemical, and genetic tumor alterations that are associated with rapid tumor growth, i.e., brisk mitotic activity, lymphovascular invasion, tumor necrosis, and a high incidence of invasion into or through the bladder or bowel muscle at the time of diagnosis.[26,29,30] Indeed, in support of the findings reviewed above are five cases of malignancy that arose within an augmented bladder where routine cystoscopic evaluations had been normal 4–18 months prior to the development of an invasive malignancy that eventually proved to be fatal.[26,29,30]

In essence low-stage medically or surgically curative bladder cancer can rarely be detected by annual screening endoscopic and cytologic studies. Indeed, it is our belief that the costs of these studies far outweigh the prevalence of the disease and have no proven benefit in diagnosing early-stage and curable tumors.[26,29,30]

SPONTANEOUS BLADDER PERFORATIONS

This complication is associated with significant patient morbidity with a reported mortality incidence of approximately 25%.[28,35–38] Spontaneous bladder perforations may occur at any time ranging from the first postoperative year to more than 30 years following the augmentation.[28,35–38] Their incidence varies from 2% to 10% and is related to the findings of post augment, high leak point pressures, compliance with intermittent catheterization, and length of follow-up.[28,35–38]

Diagnosis of a spontaneous rupture of the augment can be problematic due to the large number of patients with impaired sensation that have undergone this procedure, e.g., patients with spina bifida or spinal cord injury. Patients with decreased sensation will frequently present with vague symptomatology, such as malaise and nausea, with or without associated diaphragmatic irritative symptoms, i.e., persistent hiccups or shoulder pain. Without interventional treatment patients will usually progress to complaints of vomiting, fever, abdominal pain with or without abdominal distention, and physical findings consistent with peritoneal irritation.[38–40] From a urologic standpoint, the differential diagnosis will be small bowel obstruction, severe

Table 62.1 Comparison of Renal Deterioration Following Bladder Augmentation With and Without Bladder Neck Reconstruction and Creation of a Continent Abdominal Stoma

Patient Categories	% of Patients With BladderCalculi	% of Patients With Kidney Stones	% With Renal Scarring or Loss of One Kidney	% With ≥Stage 3 Chronic Renal Failure	Median Length of Follow-up Since Augmentation
Bladder augmentation with bladder neck reconstruction or sling and continent stoma N = 134	22% (29/134)	16% (22/134)	31% (41/134)	11% (15/134)	14 years (10–45 years)
Bladder augmentation without bladder neck reconstruction catheterization through urethra N = 39	18% (7/39)	5% (2/39)	43% (17/39)	36% (14/39)	15 years (10–38 yrs)
Statistical Evaluation p =	0.617	0.070	0.130	0.000278	

cystitis-pouchitis, or ruptured viscus, pouch, or augment. The diagnostic test of choice is an abdominal and pelvic CT without contrast followed by a CT cystogram.[38,39]

Although case reports of successfully managing spontaneous bladder perforation by nonoperative measures, that is, larger bore urethral catheter drainage, intravenous antibiotics, and serial physical examinations, have been reported, the physician should remember the 25% mortality rate associated with this diagnosis.[41,42]

Radiographic or physical findings of extruded bladder calculi outside of the augment, the presence of omentum or small bowel within the bladder lumen, progressive peritoneal irritation, and/or hemostatic instability should prompt an immediate abdominal exploration. Surgery will require irrigation of the peritoneal cavity, repair of the bladder rupture, and consideration for externalization of the ventriculo-peritoneal shunt, if one is present.[41,42]

Preservation of Renal Function Following Urinary Conduits and Bladder Reconstruction

Following preservation of life, maintenance of renal function is one of the key metrics to appraise the worth of a genitourinary reconstructive procedure. Imperative in assessing long-term renal function following diversion or augmentation is the known decrease of glomerular filtration rate (GFR) that occurs with aging. Routine studies on the aging kidney have shown the GFR on average decreases 0.4–0.5 mL/min/BSA between the ages of 20 and 50 years and then decreases by 1.0 mL/min/BSA after the age of 50.[43,44] With these facts in mind, most authorities define an abnormal decline in renal function after urologic reconstruction as: (1) a decrease in GFR of >10 mL/min/BSA during a 10-year follow-up interval,[40,41] (2) the development of new renal scars, or (3) the onset of stage 3 renal failure (<60 mL/min/BSA).[24,28,43–45] The development of stage 3 or higher renal failure is especially concerning, due to the increased risk of cardiovascular death related to renal failure. For example, there is a 20% increased risk of cardiovascular death for patients in stage 3 renal failure and a 60% increased risk of cardiovascular death related to stage 5 renal failure.[28,45–47]

It is our belief that any assessment of current reconstructive techniques must be compared to those of the past. From this point of view, we should remember that ureterosigmoidostomy is associated with a 70% incidence of deterioration of the upper tracts, defined as the development of new renal scarring, during a median follow-up interval of 15 years.[17,48,49] Ileal conduits performed in childhood have an 80% incidence of new renal scarring during a median follow-up of 20 years.[4,18,19,24,50,51] Nonrefluxing colon conduits using a submucosal tunneled ureteroenteric anastomosis, and freely refluxing colon conduits, are associated with a 45% and 24% incidence of new renal scarring, respectively, during median follow-up intervals of 15 years.[20–24,52] The difference in the incidence of renal scarring between the nonrefluxing and refluxing colonic conduits is directly related to the development of ureteral strictures within the submucosal ureteral enteric tunnels. It is notable that tunneled submucosal ureteral enteric anastomoses are associated with a 1% incidence of ureteral enteric strictures per ureter per year. In contrast, a flush, freely refluxing ureteroenteric anastomosis has a 0.5% risk of developing a ureteroenteric stricture per year.[50–53] The more favorable results for renal preservation by colonic conduits over ileal conduits appear to be directly related to the decreased risk of stomal stenosis in colon conduits.[11,21–24] In fact, deterioration of the upper tracts following urinary conduit diversion has been found to be directly related to the development of an obstruction arising as a consequence of stomal stenosis, ureteroenteric anastomotic strictures, parastomal hernias, and/or the development of obstructive renal-ureteral calculi.[11,54] It is compounded by the concurrent medical problems of diabetes mellitus and/or hypertension.[55]

The question that arises is how well do bladder augmentations preserve renal function? In this regard we believe two dichotomous patient categories need to be compared: individuals undergoing bladder augmentation with a simultaneous bladder outlet procedure and continent abdominal stoma versus patients with a bladder augmentation catheterizing per urethra. The comparison between these two different patient populations is imperative due to the reportedly two- to fivefold increased risk of complications in patients undergoing a bladder neck procedure, augmentation, and continent abdominal stoma compared to individuals with a bladder augmentation catheterizing through the urethra.[28,31,43,54,56,57]

The comparison of how well these two different procedures have preserved renal function within our patient population is depicted in Table 62.1. It is concerning to see that renal scarring occurred in 31% (41/134) of our patients undergoing a bladder augmentation with simultaneous

bladder outlet procedure and creation of a continent catheterizable stoma and in 43% (17/39) of our patients undergoing a bladder augmentation and catheterizing per urethra, respectively, during a median follow-up of 14–15 years. Indeed, the incidence of renal deterioration following an augmentation is no different from the 24–45% incidence of renal scarring following colon conduit diversion during a median of 15 years of follow-up.[20–24,52] Perhaps the most telling fact regarding why renal scarring developed following augmentation is the finding that 67% (39/58) of our patients who developed renal scarring did so after they were documented to be noncompliant with intermittent catheterization. Noncompliance is defined as a ≥3-month period where the patient catheterized three times or fewer per day.[28] The finding that significantly more patients had stage 3 or higher renal failure when catheterizing per urethra compared to abdominal stoma is intriguing (36%: 14/39 vs 11%: 15/134, respectively, p = 0.000278). This finding suggests the degree of noncompliance was higher in the individuals catheterizing through the urethra. In this regard, it is noteworthy that >80% of our patients in both patient categories were adults confined to a wheelchair and that both patient populations displayed a high incidence of obesity, with a BMI of ≥30 seen in approximately 40% of our patients in both groups (41%: 16/39 and 39%: 54/134, respectively). Moribund obesity (BMI >40) was noted in 8% of both groups (8%: 3/39 and 8%: 11/134, respectively). Interestingly, although not evaluated in our study cohort, other investigators have documented that the degree of obesity found in this patient population is significantly correlated with the patient's intellectual disability.[58–61] By reviewing our data and the existing literature, we hypothesize that the degree of noncompliance with intermittent catheterization is lessened by the use of a catheterizable abdominal stoma. Indeed, we believe that the combination of limited mobility, obesity, and decreased intellectual acuity makes management of these patients by a continent stoma both attractive and problematic. It is attractive because the abdominal stoma makes the catheterization easier, but problematic in that obesity has been found to be significantly associated with the risk of stomal stenosis, stomal retraction, and difficulty with catheterization.[62]

We also believe it is imperative to point out that long-term follow-up of this patient population reveals that the majority of patients did not manifest their noncompliance with catheterization until their late teens, twenties, and even thirties, decades after their surgical procedure.[28] Whether this increase in noncompliance is due to the greater independence of the patient from their caregivers, the increased frequency of risk-taking activities common in adulthood (i.e., drug and alcohol use), or the difficulty that may accompany catheterization and the slow but steady increase in obesity that occurs with aging, is open to conjecture.

Surgical Complications

BLADDER AND RENAL CALCULI

Bladder stone formation following urologic reconstruction is directly related to the type of augmentation performed, the use of a continent catheterizable abdominal stoma, patient compliance with medical directives, and length of follow-up.[28,31,37] Of note is that the incidence of bladder stones following augmentation has significantly decreased over the past 2–3 decades. For example, in the early 1980s 50% of the individuals undergoing an ileal or colonic bladder augmentation developed a bladder calculi within 5 years of the augmentation, and 50% of the patients that developed a bladder stone had a recurrent bladder stone within 5 years.[28,31,54,56,63] The metabolic composition of these stones was found to be struvite, i.e., infectious, in etiology in 70% of cases. Thirty percent of the bladder stones were, however, composed of metabolic active components, e.g., calcium phosphate or calcium oxalate.[64] Stone analysis usually revealed that the calcium salts had precipitated around a mucous core, with approximately 85% of the stones concurrently having positive bacterial cultures.[63,64] The finding of metabolically active calcium phosphate stones within a bladder augment is not surprising, based on the high alkalinity of the urine following either augmentation or creation of a continent urinary reservoir with ileum or colon. Specifically, alkaline urine is invariably present due to ammonium chloride absorption and bicarbonate secretion from the bowel wall. Compounding the problem of an elevated pH are the low levels of urinary citrate, a known urinary inhibitor of stone formation. Hypocitraturia is invariably present and directly related to the presence of chronic bacteriuria, with the vast majority of bacteria actively catabolizing citrate. The combination of elevated urinary pH, retained mucus serving as a nidus for crystallization, chronic bacteriuria, and low urinary citrate creates the perfect environment for the precipitation of calcium salts.[65]

Over the past 3 decades, significant strides have been made in decreasing the incidence of stone formation following augmentation or continent urinary diversion.[28,56,63,66] The decrease in the incidence of stone formation has been achieved predominantly by irrigation of the bladder with a minimum of 250 mL of water or saline solution on a daily basis. Use of high-volume daily irrigations coupled with a minimum of four times daily catheterization schedule has been documented to decrease the incidence of chronic bacteriuria, symptomatic UTIs, and bladder stones.[28] Currently, if patients are compliant with high-volume daily bladder irrigations, approximately 10% of the patients will develop a bladder stone by the tenth postsurgical year.[27,28,31,54,56,63,64,67,68]

Although high-volume bladder irrigations have helped to reduce bladder stone formation, it is far from a panacea.[28,31] In patients presenting with a second bladder stone, despite high-volume irrigation, 30% will have a third recurrent bladder stone within 5 years. Metabolic evaluations of patients with recurrent bladder stones will reveal hypocitraturia in >90% of individuals. In addition to the almost ubiquitously found hypocitraturia, either coexisting low 24-hour urinary volumes (<1600 mL) hypercalciura or hyperoxaluria will concurrently be found in one-third of the patients. Although treatment of metabolic abnormalities has been documented to decrease renal calculi, it is controversial if treatment of underlying metabolic abnormalities will reduce the incidence of recurrent bladder calculi.[28,72,73] In fact, in our experience with patients with recurrent bladder calculi and a coexisting identifiable metabolic abnormality, correction of the metabolic abnormality did not significantly decrease the risk of recurrent bladder stone formation compared to the controls.[28]

Once we recognized that treatment of the underlying metabolic abnormalities was not reducing the incidence of recurrent bladder stones, we attempted to decrease recurrent stone formation using mucolytic agents, such as 20% *N*-acetylcysteine or 10–20% urea instilled in the bladder at night along with high-volume bladder irrigation.[28,66,74,75] It was our hope that the addition of mucolytics would enhance dissolution of the mucous nidus and decrease the incidence of recurrent stone formation. Unfortunately, in a clinical trial comparing the use of high-volume bladder irrigation alone compared with high-volume bladder irrigation with the use of indwelling mucolytics overnight, we found no difference in stone formation between the two groups (30% at 5 years).[28] In essence, in patients who experience recalcitrant bladder stone formation following augmentation, we have found that neither treatment of the underlying metabolic abnormality nor the use of mucolytic agents decreased the frequency of recurrent stones over high-volume bladder irrigation alone.[28] This latter finding has been confirmed in a double-blind placebo-controlled study by N'Dow and associates.[76] These authors found that neither *N*-acetylcysteine nor ranitidine, an H_2 blocker that reduces mucus secretion, was found to be of any benefit over placebo alone in the prevention of recurrent bladder calculi.[74,76]

The question arises as to what to do with this difficult patient population. Currently, in patients of ours who are forming recurrent bladder stones, we will, in addition to the high-volume bladder irrigations (250 mL per day), use a 60-mL solution of 20% acetylcysteine placed into the bladder at night. In patients with concurrent hypocitraturia, we will also correct their urinary citrate levels.[28,57,66,74,77] We would caution that we have absolutely no clinical documentation that this treatment will substantially decrease the risk of additional stones, and this treatment regimen is done as an empiric trial.

During our 20-year follow-up of patients with an ileal or colonic bladder augmentation, we have found that approximately 15% of patients will develop a renal stone, with a median time to stone development post augmentation of 16 years (see Table 62.1).[26,28,76,78] Stone analysis will reveal the renal calculi to be of infectious etiology, i.e., struvite, in 40% of cases. The struvite calculi will invariably be associated with a urease-splitting organism colonizing the upper tract. In these circumstances assessment for vesicoureteral reflux may be merited, and it is our unsubstantiated belief that free reflux of mucus into the collecting system results in a high risk of stone recurrence. Consideration for repair of the reflux, if found, should be given. Interestingly, the majority of renal stones within this patient population are associated with metabolic abnormalities such as hyperoxaluria, hypocitraturia, hyperuricosuria, and hypercalciura.[78] The induction of hyperoxaluria, hypocitraturia, and hyperuricosuria are believed to arise as a consequence of a shortened bowel with rapid bowel transit time, saponification of calcium to fatty stools, chronic bacteriuria, and metabolic acidosis. The level of hyperoxaluria can also be affected if chronic antibiotic suppression is used resulting in loss of *Oxalobacter formigenes* the gut flora that metabolizes intestinal oxalate. Hypercalciuria classically arises in patients with a known neuropathy due to impaired mobility, or mobilization of calcium phosphate from bony stores to buffer the metabolic acidosis induced by the augment.[13,28,50,65,69–71,78]

NEED FOR SECONDARY AUGMENTATIONS

The need for a repeat or secondary augmentation has been reported to be necessary for 5–10% of patients.[31,37] The need for re-augmentation usually comes to attention due to the findings of either persistent or new onset of urinary incontinence or hydronephrosis. The need to re-augment is confirmed by urodynamic evaluation.[31,37] Urodynamic findings will reveal either impaired compliance or resumption of bladder/bowel contractions. The findings of impaired compliance are believed to be due to an inadequate-sized initial bladder augmentation, vascular impairment of the augment resulting in its fibrosis, or the inherent native characteristics of the augmenting segment.[11,79] Regarding the inherent characteristics of the augmenting segment both the stomach and sigmoid colon have been found to be problematic.[4,51,80] Specifically, ileal or ascending colon augments have been shown to improve their compliance and subsequently increase the bladder capacity on serial postoperative urodynamic studies over the first 3–5 years post augmentation. In contrast, gastric augments exhibit little to no improvement in compliance following the initial postoperative urodynamic evaluation, i.e., no serial improvement in compliance. The problem with sigmoid augmentation relates to its ability to redevelop strong autonomic contractions despite its detubularization at the time of augmentation. The resumption of high-pressure sigmoid mass contractions is associated with upper tract deterioration, urinary incontinence, and spontaneous bladder perforations. These clinical findings strongly suggest that close long-term observation of patients undergoing augmentation with gastric or sigmoid segments is necessary, especially if these procedures are combined with a bladder outlet procedure.[31,38]

SMALL BOWEL OBSTRUCTION

The need for hospitalization to manage small bowel obstruction is dependent upon the length of follow-up. During the first 2 decades post augmentation, hospitalization will be required in 10–15% of patients, with exploratory laparotomy required in 5%.[27,31,37,81] Of note is that patients requiring exploration for a small bowel obstruction will frequently be found to have an internal hernia with the small bowl volvulus intricately involving the vascular pedicle to the augment or continent stoma. Damage to the blood supply to the augment or stoma is, therefore, a distinct concern at the time of surgery.[27,31,37,81]

STOMAL REVISION OF URINARY CONDUITS OR REVISION OF CATHETERIZABLE LIMB

The incidence of stomal complications in both urinary conduits and catheterizable limbs is directly related to the surgeon's experience, the patient's body mass index, and the length of follow-up.[24,71,82–88] Regarding urinary conduits, stomal, midloop stenosis or parastomal hernias will occur in up to 40% of ileal conduits and 15% of colon conduits by the tenth postoperative year.[24,51,89] As noted previously, these complications are frequently related to deterioration of the upper tracts, and routine evaluation for their presence should be an integral part of the patient's follow-up. If obstruction of the stomal outlet is found it should be

immediately addressed by either long-term radiologic intervention with interval stenting of the kidneys and conduit, or surgical revision.[32,82,83,85,90]

Approximately 75% of children undergoing a bladder augmentation will have the simultaneous performance of a continent catheterizable stoma. The continent stoma is classically performed to either aid the child in his/her ability to catheterize from a wheelchair, to decrease the discomfort of catheterizing through the urethra, to prevent problems with catheterization through a reconstructed bladder neck, or due to surgical closure of the bladder neck. Catheterizable channels are performed using either the principles of the Mitrofanoff procedure, e.g., appendovesicostomy, Montie-Yang tubes, or tapered ileal tubes with a reinforced ileocecal valve.[32,71,82–88] Postoperative complications with stomal leakage of urine are reported to occur in 5–10% of the patients. Incontinence secondary to a faulty valve may be treated with either a bulking agent or revision of the anastomosis. However, if on urodynamic evaluation urinary incontinence is found to be due to persistent elevations in storage pressures or recurrent mass contractions of the augmented bladder, re-augmentation of the bladder, not stomal revision, will be necessary. On occasion we have seen the delayed onset of stomal-site urinary incontinence develop years to decades following the surgical procedure. The late onset of stomal incontinence is frequently due to the development of obesity, with successful weight loss resulting in the patient regaining urinary continence. Alternatively, we have also seen the delayed onset of incontinence secondary to development of a false passage within the catheterizable limb that will require surgical revision.[71,85–88] Difficulty with catheterization of the continent limb will be reported in 20% of the patients managed by appendicovesicostomy and Montie-Yang procedures, and in 10% of patients with a tapered ileal channel, by their tenth postoperative year. Unfortunately, we have seen this complication continue to increase with time, especially in patients who gain significant weight as they mature, with difficulty with catheterization reported to occur in up to 50% of the patients by the third postoperative decade.[32,51,71,85–88] Difficulty with catheterization may arise secondary to either stenosis at the cutaneous or midfascial levels, kinking of the stoma channel, or creation of a false passage or diverticulum within the catheterizable limb. Approximately 50% of the patients may be managed by use of an L-shaped stent at night time. Unfortunately, it will not work in all patients, and approximately 50% of patients will require a formal revision or creation of a new channel.[45,51,80,86,88,89,91]

Medical Complications Following Bladder Augmentation or Urinary Diversion

CHRONIC BACTERIURIA

In patients undergoing bladder augmentation or continent urinary reservoir formed with ileum or colon, we have found the incidence of asymptomatic bacteriuria to range between 45% and 85% in routinely obtained urine cultures.[26,28,86] Interestingly, we have found the incidence of asymptomatic bacteriuria and symptomatic UTIs to be directly related to both the volume of fluid used for daily bladder irrigations and the patient's compliance with physician recommendations.[28] Specifically, daily bladder irrigations of ≥240 mL along with a minimum of four times per day catheterization is associated with a significant reduction in the incidence of asymptomatic bacteriuria and symptomatic UTIs.[28]

Whether the presence of chronic bacteriuria is associated with a decrease in renal function is controversial. The majority of clinical studies have found that chronic bacteriuria is not associated with an elevation in antibacterial serum titer antibodies or markers for systemic inflammation. Therefore treatment is currently not recommended.[43,44]

METABOLIC SEQUALAE

The metabolic consequence of hyperchloremic metabolic acidosis arises as a result of urine contacting the ileal-colonic epithelium. Due to the enteric epithelium's functional nature, it will absorb ammonium chloride and, to a lesser extent, secrete bicarbonate. The frequency of this complication is related predominantly to the length of bowel incorporated into the reconstruction, urinary dwell time, and the patient's renal function.[43] With these three factors in mind, it is not surprising the incidence of this disorder is greatly dependent upon the type of reconstruction performed. Specifically, the reported incidence of hyperchloremic metabolic acidosis that requires treatment (serum bicarbonate <21 mEq/mL or chloride >110 mEq/dL) will occur in approximately 50% of the patients following ureterosigmoidostomy, in 20% of patients with an ileal or colonic augmentation, Indiana pouches or ileal neobladder, and in 10% of patients with an ileal or colonic conduit.[11,17,45,50,51,82,92] Treatment of the metabolic acidosis is with either potassium citrate or sodium bicarbonate therapy. To prevent bony demineralization that may arise secondary to the chronic metabolic acidosis, the addition of a daily multivitamin and mineral supplementation to enhance vitamin D and calcium intake may be considered.

It is noteworthy that in a patient whose GFR <45 mL/min/BSA (stage 3B renal failure), renal function will be unable to compensate for the excess endogenous acid load induced by the absorption of ammonium chloride caused by inserting a ileal or colon segment into a urinary reservoir. The resultant hyperchloremic metabolic acidosis and hyperfiltration injury from excess urinary absorption by the bowel segment may, hypothetically, hasten renal failure in this subset of patients. Due to this sequela, urinary conduits are preferred in patients whose GFR ≤50 mL/min/BSA.[43,93]

Of particular note when we are discussing metabolic sequalae of bladder augmentation are the complications found following a gastric cystoplasty. The conceptual foundations of why a gastric augment should be used for urologic reconstruction are based on four major points: (1) Patients with renal failure (stage 3B or higher) would be spared the increased risk of metabolic acidosis and accelerated renal failure by using a segment of bowel that is non-absorptive in nature and associated with acidic loss, i.e., HCl secretion by gastric epithelium into the urine. (2) Use of the gastric augment was recommended in patients where bowel transient time was already compromised due to inadequate length, e.g., cloacal exstrophy. Gastric augments were recommended in this patient population to

reduce the risk of the short gut syndrome and fecal incontinence. (3) Use of a gastric augment decreases the risk of recurrent UTIs in immunosuppressed patients. In this situation, the acidotic secretion from the gastric segment would make the bladder unsuitable for bacterial colonization. Subsequently, this would decrease the risk of symptomatic UTIs and reduce the incidence of pyelonephritic stimulated transplant rejection episodes. (4) It was also hypothesized that the stomach wall, because of its well-defined mucosal and muscular components, would provide a better technical environment for a tunneled anastomosis, reducing complications related to reimplantation of the ureter or continent catheterizable channel.[57,81,94]

Despite its hypothetical advantages, the clinical use of gastric cystoplasty was found to be associated with a multitude of complications.[81] Specifically, one-third of the patients undergoing this type of augmentation complained of hematuria-dysuria syndrome, i.e., bladder irritation secondary to hypergastrinemia and HCl secretion.[51,57,94,95] The symptomatology of the hematuria dysuria syndrome can, at least, be partially combated by the use of H_2 blockers and proton pump inhibitors. Unfortunately, these symptoms cannot all be resolved with pharmacologic therapy, and approximately 15% of patients, i.e., approximately half of the patients with this syndrome, will undergo resection of the gastric augment as a consequence of refractory symptomatology.[51,96] Five percent of gastrocystoplasty patients will also develop episodic hypochloremic, hypokalemic metabolic alkalosis.[4] This metabolic abnormality is usually stimulated by a state of dehydration and is associated with life-threatening cardiac arrhythmia and sudden death.[57] In addition to the aforementioned complications, 1–2% of patients will develop the dumping syndrome, resulting in a significant decrease in gastric-bowel transit times. This complication, if it occurs in a patient with an already foreshortened gut, can be devastating.[4,51,57,96] Not to overstate the problems arising with gastrocystoplasty, the physician should also be aware that this procedure is associated with a two- to threefold increased risk of neoplasia.[26,29,33] Due to the multitude of long-term complications found following gastrocystoplasty this procedure has been largely abandoned from the surgical armamentarium.[51,57]

HYPERCHLOREMIC METABOLIC ACIDOSIS–INDUCED OSTEOPOROSIS OR GROWTH RETARDATION

Chronic untreated hyperchloremic metabolic acidosis may on rare occasions be associated with hypocalcemia. Specifically, metabolic acidosis results in a decreased reabsorption of renal calcium and a subsequent increase in osteoclastic bone activity to balance serum calcium levels.[50,92] Combine the homeostatic calcium problem with possible malabsorption of vitamin D and dietary calcium due to steatorrhea arising from a shortened gut and it would appear that this population could be at high risk for osteoporosis and growth retardation. Interestingly, multiple large series, evaluating patients for the onset of osteoporosis or growth retardation, have revealed this to be a rare complication, presumably due to the physician's tendency to treat the underlying hyperchloremic metabolic acidosis before the onset of bony abnormalities.[43,92]

FECAL INCONTINENCE

Complications arising from the functional loss of the bowel used for urologic reconstruction are related to both the type and length of the bowel used and are highly dependent upon proper patient selection. This complication is, in general, more common when the urologic reconstruction involves the use of the ileocecal junction or large volumes of ileum (>200 cm). Use of the ileocecal junction or large amounts of ileum for urologic reconstructive purposes should not be done in patients with a previously foreshortened gut or a history of loose stools, fecal incontinence, or inflammatory bowel disease, and it is relatively contraindicated with a history of radiation enteritis.[32] Provided the physician correctly selects the patients, loose stools following urologic reconstruction, even with the removal of the ileocecal valve, will be found in <3% of patients.[32] If this complication does arise it is usually correctable with cholestyramine 4–8 g twice daily. If cholestyramine is not successful the use of gastrointestinal motility inhibitors, such as loperamide (i.e., Imodium), may be considered.[32,92] It is imperative that we stress that assessment of the patient regarding fecal continence and stool habits before urologic reconstruction is necessary to decrease the frequency of this complication. In the absence of appropriate patient selection, fecal incontinence has been reported to be as high as 20% following formation of ileocecal urinary reservoirs and ileal neobladders.[32,43,50,57]

PROTHROMBIN DEFICIENCY

Fat absorption and subsequent absorption of the fat-soluble vitamins A, D, E, and K depend heavily on the emulsification of dietary fat by bile salts. It is noteworthy that 95% of bile salts are absorbed in the preterminal and terminal ileum. Loss of ileal length results in a larger percent of bile salts reaching the colon, where they will act as a direct mucosal irritant and induce diarrhea. As more bile salts are lost, dietary fat malabsorption occurs, resulting in steatorrhea and, subsequently, the malabsorption of the fat-soluble vitamins. Deficiency of vitamin K, a necessary factor in blood coagulation, is often subtle and not clinically apparent until a major surgical procedure or traumatic injury occurs. It is therefore suggested that all patients scheduled to undergo a major procedure with a history of ileal resection or loss of ileal continuity undergo a prothrombin evaluation with correction of any identifiable anomaly prior to surgical intervention.[50,92]

B_{12} DEFICIENCY

Classically, low serum B_{12} levels will begin to show up 3–5 years post surgical reconstruction; however, due to high storage levels within the body, they may take up to 15 years to become manifest.[82,97,98] Specifically, B_{12} is bound to an intrinsic factor secreted by the parietal cells within the stomach. It forms a soluble complex that reacts with the B_{12} receptor protein within the ileal epithelial cells. B_{12} deficiency following urologic reconstruction has been found to be associated with any type of urologic surgery using any segment of ileum, i.e., ileal augmentations, ileal neobladders, ileocecal reservoirs, and ileal conduits.[97] Approximately 8–10% of patients for whom ileum is used for

reconstructive purposes will develop low serum B_{12} levels by 10–15 years of follow-up. The vast majority of patients will be able to correct the defect by increasing ingestion of B_{12} or multivitamins.[82,97,98] Long-term follow-up of this patient is mandatory to verify that oral supplementation remains successful; if not, parenteral treatment will become necessary.[97] It is noteworthy that failure to identify or correct this anomaly may be associated with peripheral neuropathy, dementia, accelerated atherosclerosis due to elevated levels of homocysteine, and megaloblastic anemia.[99,100]

Bladder Augmentations Not Using the Gastroenteric Segments

AUTOAUGMENTATION-DETRUSOR MYOMECTOMY

Autoaugmentation, also known as detrusor myomectomy, is an operation where the detrusor muscle is resected off the dome of the bladder to create a large low-pressure bladder diverticulum. It is an alternative augmentation, using native bladder mucosa as opposed to secretory gastrointestinal epithelium. Classically the operation is used only in patients with mild bladder noncompliance (>20 mL/cm H_20). At its best it results in only mild-to-moderate improvement in bladder compliance. The procedure is associated with significant problems with bladder emptying with approximately 25% of the patients needing to perform intermittent catheterization to prevent recurrent symptomatic UTIs, and 50% will eventually require an enteric augmentation due to persistent high detrusor pressures or urinary incontinence.[57,101]

URETEROCYSTOPLASTY

Ureterocystoplasty hypothetically should be the ideal augment. It is naturally lined by native urothelium and is free from metabolic disturbance and mucus production. Classically this procedure utilizes a preexisting dilated ureter for augmentation and involves a concurrent ipsilateral nephrectomy if the dilated ureter is associated with a nonfunctional kidney, or transureteroureterostomy if the ipsilateral kidney is functional in nature. Preoperative urodynamics is essential in the assessment of patients when considering this procedure. In individuals with mild bladder noncompliance (>20 mL/cm H_20) this operation's success approaches 100%. However, 75% of patients will require intermittent catheterization to prevent recurrent symptomatic UTIs.[101,102] In contrast, in poorly compliant systems (≤20 mL/cm H_20), success is <20% with greater than 80% of patients requiring re-augmentation due to persistent high bladder pressures with continued urinary incontinence or upper tract deterioration.[51,101,102]

INCONTINENT ILEOVESICOSTOMY (ILEAL CHIMNEY)

This operation is considered in children with inadequate bladder emptying and low BMI and is seen as an option of last resort. It is usually performed in severely mentally and physically compromised patients where intermittent catheterization, an indwelling suprapubic tube, or urethral catheter is not feasible.[103] This operation attaches a short portion of the ileum to the dome of the bladder allowing the patient to wear a stomal appliance bag for collection of the urine. Although short-term follow-up has been favorable, long-term follow-up evaluations have revealed multiple complications, with upper tract deterioration due to urinary stasis and stone formation found in 60% of patients at 10 years.[103,104]

Pregnancy Following Bladder Augmentation and Urinary Diversion

In patients who have undergone a bladder augmentation or urinary reservoir formation and become pregnant, the incidence of symptomatic UTIs that will require treatment during pregnancy will approach 50%. Increased urinary incontinence either through stoma or urethra will occur in 40%. Symptomatic upper tract obstruction requiring intervention will occur in 10%, and preeclampsia in 10%. In patients who have had a bladder neck reconstructive procedure and became incontinent with pregnancy, persistent postpartum urinary incontinence will result in the need for surgical intervention in 20%. Deterioration in renal function occurs only rarely and is usually associated with a pre-pregnancy creatinine of >1.2 mg/dL. It is noteworthy that 30% of patients that have a pre-pregnancy serum creatinine of >2.2 mg/dL have a permanently documented decrease in postpartum renal function.[57,105,106]

Women with a history of bladder augmentation and a bladder neck procedure are considered for cesarean section to prevent ischemic injury and pressure necrosis of the bladder neck and urethral continence mechanism during vaginal delivery. It should be noted that, although this is the standard recommendation, vaginal delivery has been proven to be a safe alternative in some of these individuals.[57,105,106]

Patient Selection

Although the complications we have reviewed following childhood reconstructive urologic procedures are myriad, the physician must weigh their occurrence against the quality-of-life improvements, in both self-image and self-esteem, noted by the vast majority of these patients following surgical reconstruction.[14,15] Assessment of the individual's intellectual and physical capability, as well as his or her ability to comply with medical directives, refrain from high-risk habits (i.e., alcohol and illicit drug abuse), and maintain long-term follow-up visits, is critical to long-term success. Indeed, it must be stressed that appropriate preoperative evaluation and patient selection are the key factors for a triumphant reconstructive procedure.

References

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Chapter 62 Questions

1. A 32-week-old premature boy is born with posterior urethral valves. He is in the operative room for endoscopic incision of his valves. However, the cystoscope is too large for the urethra. The next step is:
   a. Urethral dilation
   b. Place indwelling Foley catheter, wait 1 month, and reattempt endoscopy
   c. Percutaneous suprapubic tube placement
   d. Vesicostomy
   e. Perineal urethrostomy with valve ablation

2. A 5-kg 2-month-old boy with a history of a high imperforate anus is initially managed with a diverting colostomy. He is referred for evaluation of recurrent urinary tract infections (UTIs) and metabolic acidosis (HCO_3 of 18 mEq/mL). Evaluation reveals grade 3 bilateral vesicoureteral reflux, post-void residual urines of >100 mL, a urethral rectal fistula, and a tethered spinal cord. The next step is:
   a. Intermittent catheterization
   b. Vesicostomy
   c. Release of tethered cord
   d. Rectal pull through procedure with ligation of fistula
   e. Bilateral ureteral reimplantation

3. The bladder augmentation that is at the highest risk for developing a bladder cancer is:
   a. Ileal
   b. Gastric
   c. Ileocecal
   d. Sigmoid
   e. Ureterocystoplasty

4. An 18-year-old man with T-6 paraplegia underwent an ileal bladder augmentation and appendicovesicostomy 3 years ago. He presents with a history of anorexia, fatigue, lethargy, malaise, and chronic hiccups for the past week. The next test is:
   a. Urine culture
   b. Chest x-ray
   c. Cystogram
   d. CT of the abdomen and pelvis followed by CT cystogram
   e. CT urogram

5. The most common reason for deterioration in renal function following a bladder augmentation is:
   a. Obesity
   b. Bladder stones
   c. Noncompliance with intermittent catheterization
   d. Persistent elevations in detrusor pressures post augmentation
   e. Vesicoureteral reflux

6. The decrease in the incidence of bladder stone formation following bladder augmentation from 50% in the 1980s to 10% in the 2010s is due to the use of:
   a. Mucolytic agents
   b. Potassium citrate
   c. Chronic antibiotics
   d. High-volume bladder irrigation
   e. Routine use of continent abdominal stomas

7. The majority of renal stones that develop in patients following a bladder augmentation are due to:
   a. Short-bowel syndrome
   b. Chronic antibiotic suppression
   c. Reflux of mucus into the upper tracts
   d. Proteus colonization of the upper tracts
   e. The development of bladder calculi

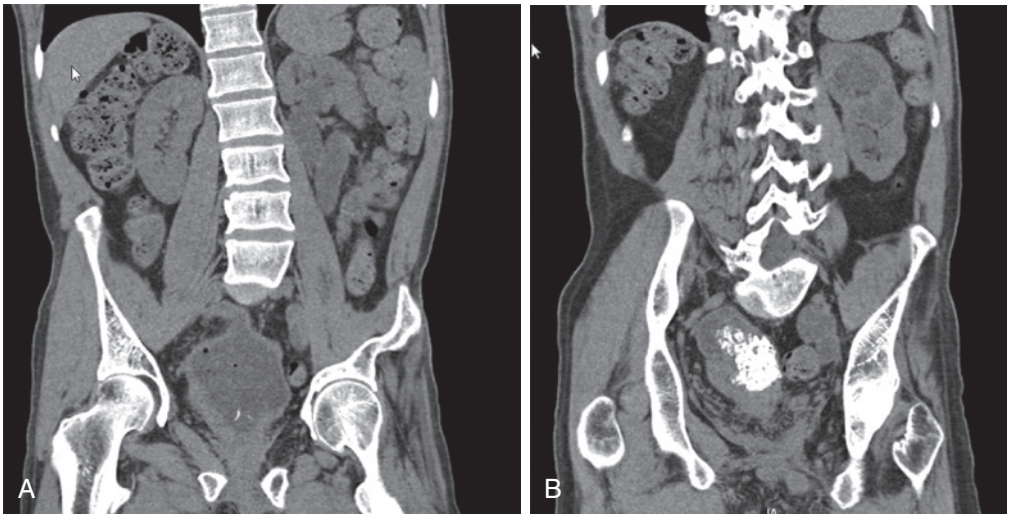
8. A 14-year-old boy with spina bifida underwent a bladder neck reconstruction, sigmoid bladder augmentation, and appendicovesicostomy 5 years ago. He complains of new onset of stomal urinary incontinence over the past month. He was empirically given a trial of antibiotics without improvement. Urine cultures are currently sterile. The next step is:
   a. Cystoscopy
   b. Urodynamic evaluation
   c. Renal and bladder ultrasound
   d. MRI of the lumbar sacral spinal canal
   e. CT scan of the abdomen and pelvis

9. A 12-year-old boy with a history of embryonal rhabdomyosarcoma of the prostate underwent a cystoprostatectomy and detubularized ascending colon pouch formation with a tapered ileal limb (Indiana pouch) 8 years ago. He now presents with an osteosarcoma of the iliac crest. Prior to extirpative surgery he should undergo:
   a. Platelet count
   b. A bleeding time
   c. Prothrombin time
   d. Partial thromboplastin time
   e. Serum lactate dyhydrogenase (LDH)

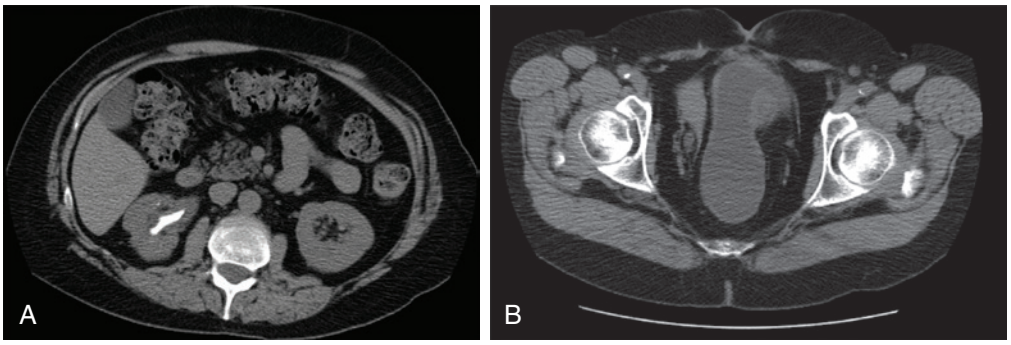
10. A relative indication for cesarean section post urologic reconstruction is:
    a. Ureterocystoplasty
    b. Continent ileocecal reservoir
    c. Sigmoid bladder augmentation with appendicovesicostomy
    d. Ileal bladder augmentation with reconstruction of bladder neck and appendicovesicostomy
    e. Presence of an artificial urinary sphincter at the bladder neck

Case Studies

1. A 21-year-old male with a history of spina bifida has been lost to follow-up for the past 5 years. His status is post bladder neck ligation, ileal bladder augmentation, and appendicovesicostomy 12 years ago. He complains of new onset of incontinence per stoma and multiple symptomatic febrile UTIs over the past year. CT scan without contrast is shown in Case Fig. 62.1. The next step is:
   a. MAG 3 diuretic renal scan
   b. Cystostogram
   c. Cystoscopy
   d. Percutaneous nephrostomy
   e. Percutaneous suprapubic tube placement



Case Figure 62.1



Case Figure 62.2

2. A 57-year-old woman with a history of classical bladder exstrophy underwent a staged bladder reconstruction, eventually becoming continent following a sigmoid colon bladder augmentation, bilateral Cohen cross-trigonal ureteral reimplantations, and bladder neck reconstruction. She presents for her annual follow-up evaluation with complaints of right flank and pelvic pain. CT images without contrast are shown in Case Fig. 62.2. The next step is:
   a. Dimercaptosuccinic acid (DMSA) renal scan
   b. Cystoscopy
   c. Ureteroscopy with laser lithotripsy
   d. Percutaneous nephrolithotomy
   e. MAG 3 diuretic renal scan

Answers

1. **d.** In newborn boys with posterior urethra valves urethral catheterization, classically with a 5- to 8Fr pediatric feeding tube, is initially used to decompress the upper tracts. Placement of a feeding tube over a Foley catheter is preferred to prevent inadvertent blowing up of the Foley balloon in the urethra thereby preventing urethral injury. The temporary placement of the pediatric feeding tube allows electrolyte stabilization of the infant and will passively dilate up the urethra to allow for endoscopic placement of instruments. If at the time of attempted endoscopic incision of the posterior urethral valves the endoscopic instrument does not fit, the next step is cutaneous vesicostomy. Percutaneous placement of a suprapubic tube in infants should be done as a temporary procedure if the physician is unable to place a urethral catheter at birth. In a child with posterior urethral valves whose bladder is distended into the abdominal cavity, placement should always be done under ultrasound guidance to prevent injury to the surrounding organs, i.e., bowel. Although perineal urethrostomy and valve ablation is an alternative approach, it does place the infant at risk for urethral stricture with maturation and veiscostomy with delayed valve resection is a safer approach.
2. **b.** Imperforate anus is associated with six major urologic anomalies: (1) renal agenesis, (2) vesicoureteral reflux, (3) rectal-urethral or vesical fistulas, (4) neurogenic bladder secondary to a tethered cord or partial sacral agenesis, (5) cryptorchidism, and (6) erectile dysfunction. Infants with imperforate anus and rectal-urethral fistulas will frequently present with recurrent UTIs and/or metabolic acidosis from urine absorption by the colonic epithelium. In infants too small to undergo a complex posterior sagittal repair (i.e., <10 kg), a temporary vesicostomy will relieve both symptoms. In this child with a concurrent neurogenic

bladder secondary to a tethered cord, the vesicostomy will also temporarily treat the bladder dysfunction reducing the risk of upper tract deterioration. Release of the tethered cord will be necessary; however, it may or may not improve bladder function and would not relieve the recurrent UTIs related to the rectal-urethral fistula. Intermittent catheterization would be highly problematic with the rectal-urethal fistula, the catheter frequently either hanging up at the fistula site or passing through the fistula into the rectum. Vesicoureteral reimplantation is not recommended in a infant due to technical problems and would not resolve the metabolic acidosis or recurrent bacteriuria.

3. **b.** The two patient categories that are at the highest risk for developing a cancer after an augmentation are patients who were augmented with the stomach, and individuals undergoing an augmentation that are on immunosuppression. These two patient populations are at a two- to threefold increased risk for developing a malignancy, a risk of approximately 3% per decade post augment.
4. **d.** The majority of bladder augments are performed in patients with a diminished sensation. In this patient population an abdominal mishap, such as appendicitis, severe pouchitis (infection of the augmented bladder), or perforation of a bladder augmentation may present with vague constitutional and abdominal complaints. Missed diagnosis of a perforated viscus or augment within these patients can be catastrophic with a reported mortality rate of 25%. Diagnosis of an intraabdominal mishap must be ruled out during their presentation. The best test is an abdominal and pelvic CT without contrast followed by a CT cystogram. The combination of these tests has a diagnostic accuracy rate of >95% for finding clinically significant intraabdominal pathology.
5. **c.** Noncompliance with intermittent catheterization is the most common etiologic cause for both bladder perforation (85%) and upper tract deterioration (67%). Obesity, although not the most common cause for renal deterioration, has been found to be related to noncompliance with catheterization, especially in wheelchair-bound patients. Presumably these patients are often noncompliant with catheterization due to difficulty with transferring from their wheelchair to perform the catheterization. Noncompliance with catheterization in obese, wheelchair-bound patients appears to be lessened by the creation of a continent abdominal stoma. Unfortunately complications with continent abdominal stomas such as stomal stenosis and false passages have also been found to correlate with obesity. This makes creation of a continent stoma in the obese patient population a very mixed bag of blessings and woes. Deterioration of renal function is only rarely caused by persistent elevations in detrusor pressures following augmentation. Deterioration of renal function has not been found to correlate with the presence of bladder calculi.
6. **d.** High-volume irrigation of the bladder augment performed daily has been associated with a decreased incidence of bladder stone formation, decreased frequency of bacterial colonization of the bladder, and decreased incidence of symptomatic urinary stone formation. The use of chronic antibiotic suppression, potassium citrate, or mucolytic agents has not been proven to be of any benefit in the prevention of bladder stones post augmentation. The use of continent abdominal stomas is actually associated with a increased risk for bladder stone formation.
7. **a.** Short-bowel syndrome is classically associated with loss of the ileal length, especially the terminal 15–25 cm. Short-bowel syndrome is a phenomenon that occurs due to the rapid transit of bile salts, a necessary component for the metabolism of dietary fats. The majority (95%) of bile salts are resorbed in the preterminal and terminal ileum. When this region of ileum is lost, excess bile salts will enter the colon. Bile salts have a direct cathartic effect on colonic mucosa accelerating bowel transit time resulting in the loss of bile salts in the feces. Loss of bile salts results in excess fat within the intestinal lumen, i.e., steatorrhea. Under normal circumstances dietary calcium is bound to oxalate within the stool; however, in the presence of excess stool fat calcium will preferentially be bound to the fat, a process called saponification. This makes dietary oxalate more available for absorption. Excess systemic oxalate is excreted in the urine resulting in hyperoxaluria and increased risk of metabolic calculi. If the short-bowel syndrome results in excess stool loss, the high bicarbonate content of stool can result in metabolic acidosis. In turn this results in calcium phosphate absorption from boney stores in an effort to buffer the system pH, further compounding the risk of metabolic induced stones due to hypercalciuria arising from bone resorption. In general, following a bladder augmentation, 60% of upper tract stones are found to be metabolically active calculi due to one of the aforementioned abnormalities. The likelihood of metabolic stones can be further potentiated by the use of chronic antibiotics; antibiotic usage results in the loss of *Oxalobacter formigenes*, the gut flora that metabolizes intestinal oxalate. Although vesicoureteral reflux with reflux of mucus into the upper tracts and chronic infection from bladder calculi can absolutely play a role in upper tract stones, they are not the predominant etiology of renal calculi following bladder augmentation.
8. **c.** New onset of urinary incontinence following a bladder augmentation is usually secondary to a UTI, and a urine culture with appropriate treatment or an empiric trial of antibiotics is the initial first step. If incontinence persists, the differential diagnosis includes, bladder stone, resumption of bowel activity, bladder malignancy resulting in irritation and overactivity of the augment, false passage of the continent stoma, or the onset of obesity impacting the vesical leak point pressure. The most common etiology after infection is the development of a bladder stone. A renal bladder ultrasound with or without kidney, ureters, and bladder x-rays is therefore the next step. Although a complete workup with a renal bladder ultrasound, urodynamic evaluation, and cystoscopy may be pursued, the initial step is with the noninvasive ultrasound. Ultrasound preferred over a CT scan due to cost benefit. It should be noted that sigmoid bladder augments are the most likely to have resumption of intrinsic bowel contractions even with detubularization of the bowel and would be mandated in this patient if no

bladder stone, false passage, or malignancy is found. It would be extremely rare for a tethered spinal cord to present with new onset of incontinence post augmentation. Following a bladder augmentation, the augmentation will dampen out the detrusor overactivity classically found with a tethered cord. Symptoms of a tethered cord post augmentation are classically related to alterations in lower-limb functionality.

9. **c.** Abnormal absorption of all fat-soluble vitamins (A, D, E, and K) can occur with loss of the preterminal and terminal ileum. The decrease in vitamin K can be subtle and may only become manifest with uncontrollable bleeding following trauma or major surgery. Vitamin K deficiency is diagnosed by an elevation in prothrombin time. Partial thromboplastin time, bleeding time, and platelet counts will all be normal. It is recommended that all patients where ileum was used as a part of their urologic reconstruction should undergo a prothrombin time assessment prior to any major surgery. Serum LDH is used in the evaluation of hemolytic anemia and is not indicated in this patient.
10. **d.** Women with a history of bladder augmentation and a bladder neck procedure are considered for cesarean section to prevent ischemic injury and pressure necrosis of the bladder neck and urethral continence mechanism during vaginal delivery. Cesarean section is not indicated following a ureterocystoplasty, continent ileocecal reservoir, or bladder augmentation not involving a bladder neck reconstruction or closure. Interestingly, although cesarean sections are recommended following bladder neck reconstruction. No indications for a cesarean section exist directly related to a prior placement of an artificial urinary sphincter at the bladder neck. Multiple vaginal deliveries have successfully occurred in this patient population without sequalae.

CASE STUDIES

1. **c.** In this patient, who has been lost to follow-up, the history of recurrent UTIs and new onset of urinary incontinence is most commonly due to bladder stones. CT scan documents the presence of multiple bladder stones along with left hydroureteronephrosis. These findings are highly concerning for the development of noncompliance with routine intermittent catheterization. The first step should be endoscopic evaluation of the pouch. This will confirm the presence of bladder calculi and rule out the presence of a concurrent invasive bladder tumor. The hydroureteronephrosis could be due to the presence of vesicoureteral reflux, edema at the ureterovesical junction due to multiple bladder stones, or the concurrent development of a tumor associated with chronic bladder calculi that is invasive at the sight of the left trigone. If cystoscopy confirms the absence of tumor, removal of the stones by either an endoscopic or open approach is the next step. Evaluation for the etiology of hydroureteronephrosis should be delayed until after the stones have been removed. The hydroureteronephrosis will almost invariably resolve and was secondary to inflammation either causing obstruction of the ureterovesical junction or vesicoureteral reflux.
2. **b.** CT images show both right renal calculi and a filling defect within the bladder. Cystoscopy with biopsy of the mass is the next step. This patient had a highly aggressive adenocarcinoma of the augment wall. She was treated with percutaneous nephrolithotomy and 1 week later underwent a radical cystectomy and colon conduit urinary diversion. No assessment of renal function was performed, due to the need to preserve renal function to enable the chemotherapy required by the majority of these patients. Despite cystectomy with clear surgical margins and negative lymph nodes, she developed metastatic disease within 6 months. Chemotherapy and radiation therapy failed to halt the rapidly progressive disease and she died 15 months post surgery. Although she initially presented with organ-confined disease, 80% of patients will present with locally advanced disease or nodal metastasis at the time of diagnosis, with a cancer-specific mortality of 80% at 18 months following the diagnosis.

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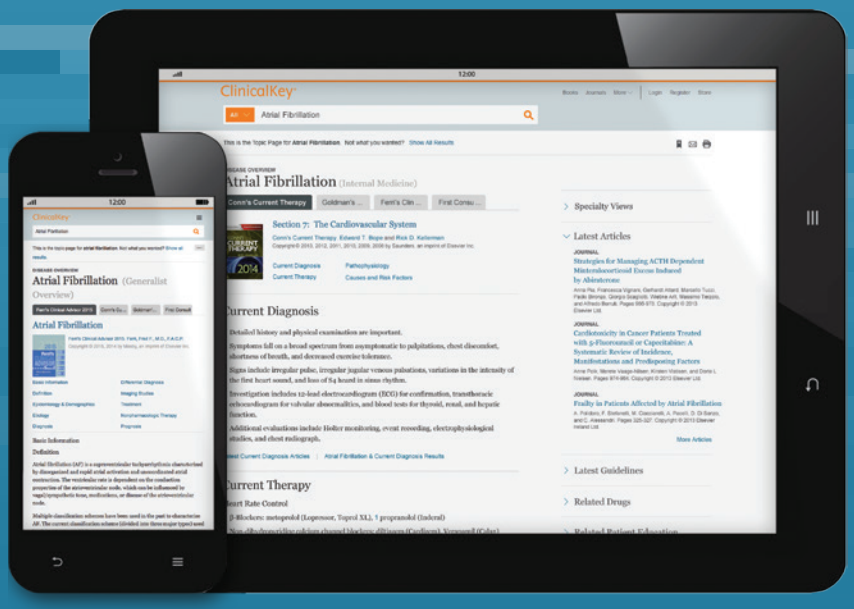
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