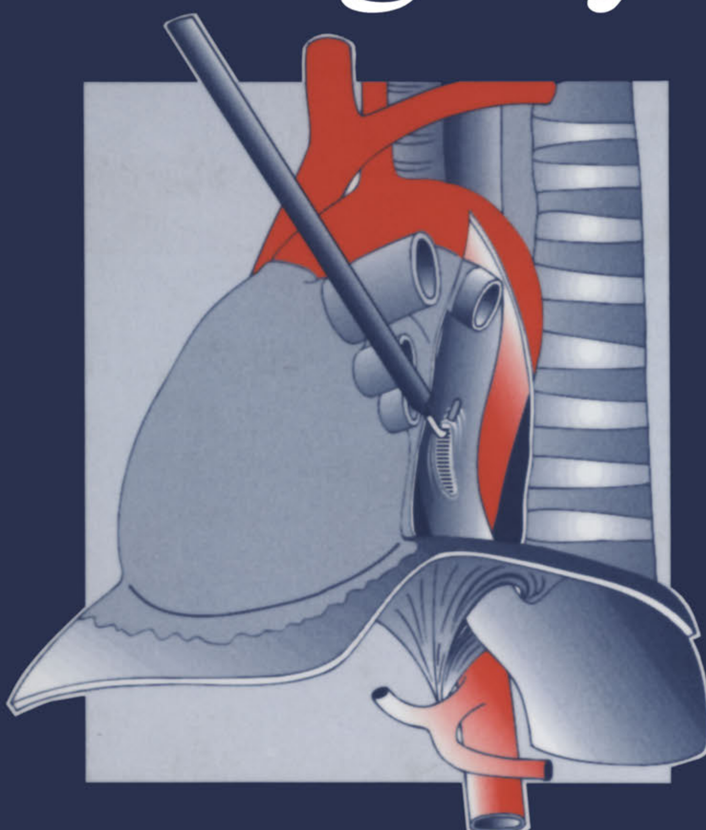
A. Cuschieri · G. Buess
J. Périssat (Eds.)

Operative Manual of Endoscopic Surgery



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Operative Manual of Endoscopic Surgery

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A. Cuschieri, MD
Ninewells Hospital and Medical School, Dept. of Surgery
University of Dundee
Dundee DD1 9SY, Scotland, UK

G. Buess, MD
Minimal Invasive Chirurgie, Abt. für Allgemeinchirurgie
Klinikum Schnarrenberg, Eberhard-Karls-Universität
Hoppe-Seyler-Str. 3, 7400 Tübingen, FRG

J. Périssat, MD
Cliniques Chirurgicales, 311 Boulevard du Président Wilson
33200 Bordeaux, France

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Preface

In putting together this manual of endoscopic surgery, we have sought to cover the three essential components of the new surgical approach: the technological aspects, the basic endoscopic surgical skills, and the operative techniques. Visualization of the operative field, exposure and execution of remote manipulations are dependent on optimal function of the ancillary apparatus without which endoscopic surgery cannot be practised. Familiarity of the surgeon with the basic physical principles of the various devices employed in this technology-dependent form of surgery ensures safe use, prolonged equipment life and smooth execution of surgical endoscopic interventions. Equally important is the acquisition of the basic skills of endoscopic surgical practice, since these differ in several important respects from those of conventional open surgery. Mastery of the craft of endoscopic surgery requires a determined commitment to training and is no easy option, but once acquired is rewarded by the extreme professional satisfaction experienced when one witnesses the remarkable progress of patients who have undergone major surgical interventions, with minimal discomfort and pain, lower morbidity and rapid return to gainful employment. The new approach has taken the "sting" out of surgical treatment and made it more acceptable to our patients. Quite apart from cost considerations, this aspect alone justifies the extra effort and investment needed for the further advancement of endoscopic surgery.

Our task in compiling this operative manual was thus an ambitious one. A large number of illustrations had to be produced, many requiring sophisticated computer graphics. This aspect of the book, which we believe to be unrivalled, incurred considerable time and effort on the part of both the editors and the medical artist Mathias Wosczyna, and to a large measure delayed completion of the book. Nonetheless, we believe that these high-quality illustrations are crucial in conveying the basic concepts behind both the principles governing the safe usage of the equipment employed in endoscopic surgery and the basic skills needed to execute the various steps of the ever-increasing variety of endoscopic operations.

Such is the pace of development of endoscopic surgery that we realized at the outset that this operative textbook would always be incomplete no matter when it was published. The decision has therefore been taken to publish supplements annually between editions of the manual. The first of these is planned to appear in the first half of 1993.

We have endeavoured to emphasize the practical aspects of each operation and have adopted a uniform style of presentation. For each procedure, detailed description of the special instrumentation needed and the position of staff and equipment is accompanied by a step-by-step account of the execution of the operation.

The task, though arduous, has been pleasant, and we are grateful to the authors for their excellent contributions and to our publishers, especially Dr. Claudia Osthoff, for constant support and encouragement. We hope that surgeons will find in this manual information which will be of benefit to their surgical practice. The book certainly reflects our many years of commitment and dedication to the development of this exciting field.

A. Cuschieri   G. Buess   J. Périssat

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List of Contributors

H. D. BECKER, MD
Abt. für Allgemeinchirurgie
Klinikum Schnarrenberg
Eberhard-Karls-Universität
Hoppe-Seyler-Str. 3
7400 Tübingen
FRG

G. BUESS, MD, FRCS Ed
Abt. für Allgemeinchirurgie
Klinikum Schnarrenberg
Eberhard-Karls-Universität
Hoppe-Seyler-Str. 3
7400 Tübingen
FRG

A. CUSCHIERI, MD, ChM, FRCS Ed
Ninewells Hospital
and Medical School
Department of Surgery
University of Dundee
Dundee DD1 9SY
Scotland, UK

F. DUBOIS, MD
Hôpital International
de L'Université de Paris
42 Boulevard Jourdan
Paris (XIV)
France

E. FRIMBERGER, MD
Technische Universität
II. Medizinische Klinik
und Poliklinik
Ismaninger Str. 22
8000 Munich 80
FRG

R. GER, MD, FRCS, FACS
Winthrop-University Hospital
Department of Surgery
259 First Street
Mineola, New York 11501
USA

F. GÖTZ, MD
St. Elisabeth-Krankenhaus
Chirurgische Klinik
Abt. Laparoskopische Chirurgie
Von-Werth-Str. 5
4048 Grevenbroich 1
FRG

N. KATKHOUDA, MD
University of Nice-Sophia Antipolis
Department of Digestive Surgery
Video-Surgery and Transplantations
Hôpital Saint-Roch
06006 Nice
France

J. KECKSTEIN, MD
Universität Ulm
Frauenklinik
Prittwitzstr. 43
7900 Ulm
FRG

G. LENZ, MD
Klinik für Anaesthesiologie
und Transfusionsmedizin
Abt. für Anaesthesiologie
Hoppe-Seyler-Str. 3
7400 Tübingen
FRG

A. MELZER, MD
Universität Tübingen
Chirurgische Klinik
Hoppe-Seyler-Str. 3
7400 Tübingen
FRG

B. MENTGES, MD
Abt. für Allgemeinchirurgie
Klinikum Schnarrenberg
Eberhard-Karls-Universität
Hoppe-Seyler-Str. 3
7400 Tübingen
FRG

J. MOUIEL, MD, FACS
University of Nice-Sophia Antipolis
Department of Digestive Surgery
Video-Surgery and Transplantations
Hôpital Saint-Roch
06006 Nice
France

M. B. NARUHN, MD
Abt. für Allgemeinchirurgie
Klinikum Schnarrenberg
Eberhard-Karls-Universität
Hoppe-Seyler-Str. 3
7400 Tübingen
FRG

L. K. NATHANSON, MB, CH, B, FRCS
Department of Surgery
Royal Brisbane Hospital
Queensland
Australia

M. PAZ-PARTLOW, MFA
Cedars-Sinai Medical Center
8700 Beverly Boulevard
Los Angeles
California 00048-1869
USA

J. PÉRISSAT, MD
Cliniques Chirurgicales
311 Boulevard du Président Wilson
33200 Bordeaux
France

A. PIER, MD
St. Elisabeth-Krankenhaus
Chirurgische Klinik
Abt. Laparoskopische Chirurgie
Von-Werth-Str. 5
4048 Grevenbroich 1
FRG

H.-D. REIDENBACH, MD
Institut für Hochfrequenz-
und Übertragungstechnik
Betzdorfer Str. 2
5000 Cologne 21
FRG

S. M. SHIMI, MB, ChB, BSC, FRCS
Department of Surgery
Ninewells Hospital and Medical School
University of Dundee
Dundee DD1 9SY
Scotland, UK

R. WITTMOSER, MD
Institut für Neurovegetative Chirurgie
und Endoskopie
Degerstraße 10
4000 Düsseldorf 1
FRG

Introduction and Historical Aspects

A. Cuschieri and G. Buess

Introduction

It is difficult to give a chronological account of events that led to the emergence of endoscopic surgery (ES) since this practice is still in its infancy, though its evolution during the past few years has been not far short of meteoric. Some would regard ES as a logical extension of endoscopy, which has progressed to interventional procedures during the past 25 years. Despite the essential role of endoscopy, this view of ES is incorrect since, in all but the approach, this new surgery is intended to do no more and no less than conventional open surgery. In this respect, laparoscopic cholecystectomy and open cholecystectomy constitute the same surgical treatment – safe removal of the gallbladder – following the surgical steps and guidelines which have been established since Langenbuch performed the first cholecystectomy over 100 years ago.

Indeed the essential attribute of this new surgical approach is the execution of established surgical operations in a manner which leads to the reduction of the trauma of access and thereby accelerates the recovery of the patient. In this respect it is far wiser that we should adapt and develop existing technology to enable the performance of well-tested and validated procedures than embark on new, substitute and invalidated operations imposed by the restrictions of the current technology. In our enthusiasm for the new approach we must not overlook sound surgical principles or compromise established surgical treatment.

This chapter outlines the important milestones, some of which date back to the turn of the present century, which have set the scene for the present interest in this new form of surgery. One thing is certain: ES has more of a future than a past.

Laparoscopy

The first published reports on the technique of laparoscopy were by Jakobeus in 1901 and Kelling in 1902, although the latter had presented his experimental observations at the meeting of the German Biological and Medical Society in Hamburg 1 year previously. In his first publication on the subject, Kelling outlined the technique of visualization of the peritoneal cavity and its contents in a dog by the insertion of a cystoscope subsequent to the creation of a pneumoperitoneum with filtered air. By contrast, Jakobeus, who based his report on his experience with the technique in humans, inserted the cystoscope directly into the peritoneal cavity without prior induction of a pneumoperitoneum. Thus the modern technique of laparoscopy is essentially that outlined by Kelling. It is difficult to determine which of these two professional rivals had the original idea, but the most likely scenario is that the development occurred independently in Sweden and Germany at about the same time.

Kalk, who pioneered the use of laparoscopy for the investigation of patients with disorders of the liver and biliary tract, introduced the oblique-viewing optic where the central visual axis of the optic is angled about 45°–50° from the longitudinal axis. This permitted a better inspection of organs as the image could be changed by altering the viewing direction of the optic such that the lens moves around the object. Kalk was an innovator, also developing other purpose-designed laparoscopic instruments. In 1929 he was the first to advocate the dual-puncture technique. This innovation enhanced the scope of diagnostic laparoscopy and opened the way for the development of operative laparoscopy. Kalk accumulated experience with over 2000 patients with impressive results and published a monograph on laparoscopy in 1951.

Fevers reviewed his experience with 50 patients in 1933 and appears to have been the first to recommend changing from room air to O_2 or CO_2 as the insufflating gas for the creation of the pneumoperitoneum.

The next significant development in the evolution of laparoscopy was by a Hungarian, Veress, in 1938. He described a spring-loaded needle with an inner stylet which automatically converted the sharp cutting edge to a rounded end incorporating a side hole. Veress designed his needle for the creation of a safe pneumothorax. His device, with some minor modifications, is the standard method used nowadays for the creation of a pneumoperitoneum.

Endoscopic Electrocoagulation

In 1934 Ruddock was the first to use biopsy forceps equipped with monopolar electrocautery during laparoscopy. Laparoscopic tubal sterilization using high-frequency monopolar electrocoagulation of the fallopian tubes was first performed in 1936 by Bosch in Germany, who employed a low-frequency generator (100 W), and a few years later in the United States by Power and Barnes (1941) who used the Bovie high-output generator capable of delivering a maximal power of 350 W. The use of monopolar electrocautery for tubal sterilization with these high-output generators led to extensive morbidity and deaths from burns to adjacent tissues and was abandoned in favour of mechanical means of achieving tubal ligation. Subsequently, bipolar electrocautery for laparoscopic tubal coagulation was first used by Fikentscher and Semm (1971); Corson et al. (1973); Rioux and Cloutier (1974). However, bipolar endoscopic electrocautery was first introduced by Wittmoser for thoracoscopic procedures in 1966.

Rod-Lens System

One of the most crucial inventions in operative laparoscopy and endoscopy in general was made by the British physicist Hopkins in 1952 who developed the rod-lens system. Prior to this development, endoscopes were constructed on an optical system which comprised relay and field lenses made from glass with long intervening air spaces. In the Hopkins system, the roles of glass and air are interchanged such that the optical system consists of air lenses and long glass spaces. As the refractive index is now predominantly that of glass, the light-transmitting capacity of the endoscope is doubled. A second advantage of the Hopkins rod-lens system relates to the "radius of clear aperture" available to the viewing optic. In the previous generation Nitze-type endoscopes, a series of very small lenses had to be assembled and mounted in a precise order inside the endoscopic tube. The position of the lenses had to be maintained by "spacer inner tubes" which had to be rifled in the long air spaces of the endoscope to minimize light reflection on their inner surface as this would lead to impairment of the contrast of the final image. This assembly resulted in a significant reduction of the clear aperture radius available to the viewing optic. By contrast, in the construction of the Hopkins rod-lens telescope, the mounting of the precision-ground glass rods, which are ten times longer than their diameter, is a simple matter and only requires very short and thin spacer tubes. This results in a significantly larger clear aperture. Furthermore, specular reflection of light is avoided since the outer surface of each rod-lens is finely ground.

The Hopkins rod-lens system remains the basis of the modern rigid endoscope used in ES. It has two problems which require further development. The first consists of light loss due to fibre mismatch at the interface between the fibre-optic light cable and the light bundles of the telescope. Different manufacturers have dealt with this problem in various ways: some have increased the size of the light bundle of the telescope or have constructed telescopes with an integral light bundle, whereas others have attached a "condensation lens" at the interface to focus the light on the light bundle of the telescope.

The second problem with the Hopkins system relates to the peripheral "barrel" distortion which is best appreciated by viewing a grid. This problem has been overcome by one of the commercial companies (Olympus) by alteration of the internal optics of the telescope to incorporate "distortion-compensating" lenses.

Laparoscopy in General Surgery and Gastroenterology

Until fairly recently, laparoscopy was widely practised by gynaecologists on both sides of the Atlantic and rarely by surgeons. In the United States it replaced culdoscopy which was popularized by Decker. Several prominent gynaecologists were instrumental in the establishment of laparoscopy as an integral part of gynaecological practice, the most notable being Palmer (France), Frangenheim (Germany), Semm (Germany), Steptoe (UK), and Phillips (USA) who founded the American Association of Gynecological Laparoscopists in 1971. Palmer and Frangenheim pioneered the angled laparoscope which incorporates a central instrument channel (the unipuncture approach). Semm developed the multipuncture laparoscopic approach using the straight telescope and multiple accessory operating cannulae. This allowed more complex surgical procedures to be performed and considerably enhanced the scope of laparoscopic surgery.

Laparoscopy became an established technique for the study of disorders of the liver and biliary tract as a result of the contributions by Kalk, Wannagat, Beck and Henning in Germany; Berci, Gaisford and Boyce in the United States; and Cuschieri in the United Kingdom. In this respect, the benefits of laparoscopy, e. g. the ability to visualize the liver, obtain cholangiograms and perform with safety a target liver biopsy of focal lesions, were stressed by these workers, but the technique failed to gain wide acceptance amongst gastroenterologists and surgeons.

No one has contributed more widely to the development and use of laparoscopy in general surgery than Berci in Los Angeles, both in the design of instrumentation and in identifying the clinical situations in surgical practice where laparoscopy would materially benefit the management of the patient. He pioneered the use of laparoscopy in the management of diagnostic dilemmas, especially in the emergency situation, and was instrumental in the development of minilaparoscopy for trauma, which permits visualization and accurate assessment of the traumatized peritoneal cavity under sedation. The superiority over abdominal lavage in establishing the need or otherwise for surgical intervention in these patients was subsequently confirmed in a prospective study designed and coordinated by Cuschieri and Berci in the mid-1980s.

Staging laparoscopy in oncological disorders was first practised by Pergola et al., Etienne et al. and Delavierre et al. (France); Canossi et al. and Spinelli et al. (Italy); Sotnikovet et al., Berezov et al. and Nikora (USSR); Cuschieri et al. and Gross et al. (UK); Devita, Gaisford, Sugarbaker and Lightdale (USA).

Development of Laparoscopic Surgery

The origin of modern laparoscopic surgery is derived from the Kiel school headed by Semm. The basic instrumentation and the heater probe were developments which emanated from this centre. Semm also added important refinements to the existing insufflators which led to the modern electronic insufflator capable of variable flow with automatic feedback controlling the insufflation to maintain a preselected intra-abdominal pressure. Semm's contribution extended beyond this, however, because he pioneered the basic surgical skills fo laparoscopic dissection, ligation (external and internal) and suturing. Virtually all the laparoscopic gynaecological procedures currently practised were first established in his centre. In addition, the basic technique of laparoscopic appendicectomy, including extraction of the organ without recourse to minilaparotomy, was developed by Semm and his group in Kiel.

Laparoscopically guided gallstone clearance was first performed in an animal model by Frimberger et al. in Germany in 1979. This followed a period of animal experimentation, as a result of which a multipuncture technique and appropriate instrumentation (trocar fixation device and spring-loaded guiding device) for safe laparoscopic cholecystotomy were developed. The method was subsequently modified and used in clinical practice by El Ghany et al. During this period, however, percutaneous gallstone extraction was performed in a number of European and North American centres under radiological as opposed to laparoscopic control (Kellet et al. 1987, Cope 1988).

Experimental laparoscopic biliary surgery was started in Dundee by Cuschieri and El Ghany in 1985. The work involved laparoscopic ligation of the cystic duct, cholecystostomy and dissection of the gallbladder. This led to cholecystectomy in the pig which was performed by Nathanson and Cuschieri in 1987 and Ko et al. in 1988. Although Mouret, in Lyon, was the first surgeon to perform the operation in the human using standard laparoscopic equipment in 1987, the procedure had been previously introduced into clinical practice in 1985 by Muehe, a surgeon from Böblingen, using a modified rectoscope with an optic and CO_2 insufflation. The first published report using the standard multipuncture technique was by Dubois et al. in 1989. Around the same time, the procedure was established in Bordeaux (Périssat), Nashville (Reddick et al.), Dundee (Cuschieri and Nathanson) and Los Angeles (Berci et al.). Since then, the practice of laparoscopic cholecystectomy has mushroomed worldwide, and to date several thousand such procedures have been performed.

The advent of laparoscopic cholecystectomy was the single most important stimulus to the development of laparoscopic and other forms of ES. Table 1 shows the various procedures which have been performed by the new approach. In this table an attempt has been made to identify the centre where the relevant procedure was first performed in the clinical situation.

Thoracoscopy and Thoracoscopic Surgery

Although there is some doubt as to who first introduced diagnostic laparoscopy, i. e. Kelling or Jakobeus, the latter, working in Stockholm, first described and practised thoracoscopy. He also performed the first thoracoscopic procedure when in 1925 he cauterized and divided adhesions between the visceral and parietal pleura in a patient suffering from

Table 1. Operations performed by the ES approach in the human

Procedures		
1920	Jakobeus	Thoracoscopic adhesiolysis
1944	Goetze	Thoracoscopic sympathectomy
1955	Wittmoser	Selective thoracic myotomy
1970	Wittmoser	Retroperitoneal sympathectomy
1979	Frimberger et al.	Laparoscopic cholecystotomy and stone clearance (animal experiments)
1981	Semm	Laparoscopic appendicectomy
1983	Buess et al.	Transanal endoscopic microsurgery
1985	Muehe	Cholecystectomy (insufflating single puncture approach)
1987	Mouret	Cholecystectomy (multipuncture approach)
1988	Buess et al.	Transanal endoscopic rectopexy
1989	Dubois	Highly selective vagotomy
1989	Nathanson et al.	Suture toilet of perforated duodenal ulcer
1989	Buess et al.	Endoscopic oesophagectomy
1990	Kakhouda and Mouiel	Truncal vagotomy and seromyotomy
1990	Cuschieri et al.	Ligamentum teres cardiopexy Ligature of bullae and pleurectomy Thoracoscopic oesophageal myotomy
1990	Ger	Laparoscopic inguinal hernia repair
1991	Cuschieri et al.	Abdominal cardiomyotomy Total and partial fundoplication

Table 2. Basic systems for endoscopic procedures

1950–1960	Wittmoser	Thoracoscopic system (unipuncture)
1965–1980	Semm	Multipuncture laparoscopic system
1980–1983	Buess et al.	Rectoscopic system
1985–1989	Buess et al.	Mediastinoscopic system
1989–1990	Cuschieri et al.	Multipuncture thoracoscopic system

Table 3. Development of photodocumentation

1952	Wittmoser	Colour slides
1965	Wittmoser	TTL (through lens measurement of light)
1968	Wittmoser	Rigid teaching attachment arm
1968	Wittmoser	16-mm endoscopic movie
1969	Wittmoser	Video documentation

pulmonary tuberculosis during the induction of an artificial pneumothorax to collapse the lung, which was then the standard treatment for this affliction.

The first thoracic denervation procedure was performed by Goetze in 1948 when he developed and performed non-selective sympathectomy. This work was continued by Cux who introduced this procedure in Innsbruck in 1949. The development of thoracoscopic surgery as we know it today stems from the sterling and pionieering work of Wittmoser (Tables 2, 3) who, over a period of 3 decades extending from 1951, developed instrumentation for executing denervation procedures both within the chest and subsequently in the retroperitoneum. Wittmoser developed and introduced into clinical practice selective thoracic vagotomy of the bronchial and abdominal branches (1955), selective sympathectomy of the rami communicantes (1962) and retroperitoneal sympathectomy (1970).

Multipuncture thoracoscopic surgery was started in Dundee by Cuschieri and Nathanson in 1989. This approach considerably enhanced the scope of thoracoscopic surgery and led to the performance of several procedures such as ligation of bullae and pleurectomy for recurrent spontaneous pneumothorax, oesophageal mobilization, and myotomy for achalasia, nutcracker oesophagus and diffuse oesophageal spasm.

The development of the operating mediastinoscope by Buess et al. (1985–1989) led to visually controlled endoscopic oesophagectomy without thoracotomy, which has been established in clinical practice in Tübingen since 1989 and which is likely to replace transhiatal blunt oesophagectomy within the foreseeable future.

Endoluminal Surgery

It is now nearly 20 years since the introduction of endoscopic sphincterotomy by Kawai et al. in Japan (1973) and Classen and Demling in Germany (1974). Regrettably this surgical procedure has been taken over by the gastroenterologists largely due to the indifference regarding the new technology by surgeons at the time. There is a lesson to be learned here, and we must ensure that future advances in interventional gastrointestinal endoscopy are embraced by surgeons and not left exclusively to those who are surgically untrained.

The most exciting development in this field is the endoluminal stereoscopic rectal surgery system developed by Buess et al. in the years 1980–1983. This allowed the performance of the first complex endoscopic surgical operation where a tumour was excised and the bowel wall sutured by purpose-designed instrumentation. The accumulated experience to date has shown that transluminal endoscopic rectal surgery permits the complete excision of large adenomas and early rectal carcinomas (pT1 and pT2) with minimal morbidity and inconvenience to the patient. Another recent development is endoscopic mucosectomy for early gastric cancer which is currently being evaluated by the Japanese.

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Part I: General

1 Nature and Scope of Endoscopic Surgery

A. CUSCHIERI and G. BUESS

Disadvantages of Open Surgery

Conventional open surgery requires that the surgeon gets to the organ which is the site of the disease. In order to achieve this objective and carry out the procedure, resective or otherwise, the relevant body cavity (chest, peritoneal cavity, pelvis) has to be laid open. Adequate exposure, which is essential for the safe and expeditious conduct of the procedure, is assisted by the use of metal retractors held by the assistants or by mechanical holders. On completion of the procedure, the body cavity concerned is repaired. Although time-honoured in our profession, this open conventional approach has certain intrinsic disadvantages which, to a large measure, influence the immediate postoperative course and delay recovery of the patient from the operative ordeal:

1. In the first instance, open exposure incurs additional trauma and therefore aggravates the postoperative catabolic response, which is accompanied by established and well-researched physical and biochemical changes, and neuropsychological sequelae which are poorly understood but which often persist for several weeks to months. These include asthenia, lethargy and mental debility.
2. Postoperative pain is largely caused by the parietal wound. In addition to patient discomfort, which often requires the administration of powerful opiate analgesics, the pain limits mobility and respiration and thereby contributes in a significant fashion to the common postoperative complications associated with surgery such as pulmonary collapse, infection and deep vein thrombosis.
3. The breach of the interior milieu caused by the opening of the body cavities results in cooling of the patient and the internal organs which lose water by evaporation. The cooling effect is especially important in children and the elderly in whom active measures are taken during the procedure to circumvent this adverse change. Particularly during long procedures, the dessication of intestinal loops, if unchecked by standard measures, is positively harmful in terms of recovery of intestinal function and integrity of gastrointestinal anastomosis created by the surgeon.
4. Retraction by metal implements, which is often quite forceful, can cause immediate obvious injury, especially to solid organs such as the spleen and liver, and may lead to shearing injuries of the mesenteries. Apart from this obvious deleterious effect, prolonged traction by metal retractors impairs tissue perfusion of the compressed tissue. Handling of the intestinal loops by the surgeon and the assistants disturbs the intrinsic myoelectric activity of the gut.
5. Several factors, e.g. exposure, cooling, handling, retraction, etc., are responsible for the inevitable adynamic ileus after open abdominal surgery. This may progress to frank intestinal obstruction in some patients and require active intervention for its relief.
6. The breach of the delicate serosal lining together with the gross manipulation lead to adhesion formation, particularly in relation to laparotomy or thoracotomy wounds. Some patients are particularly prone to adhesion formation which in the abdomen may lead to long-term intractable problems with recurrent intestinal obstructions.
7. Finally, the operative parietal wound is itself the source of significant morbidity in terms of infection, dehiscence and subsequent incisional hernia formation. Despite prophylactic measures including the use of antibiotics, postoperative wound infection remains common, prolongs hospital stay and adds significantly to the costs of surgical treatment.

Nature of ES

The hallmark of ES is the reduction of the trauma of access without compromise of the exposure of the operative field. Surgical operations are conducted by remote surgical manipulation carried out within the closed confines of body cavities or lumena of hollow organs under visual control via telescopes which incorporate the Hopkins rod-lens system linked to charge-coupled device (CCD) cameras so that the surgeon can operate across the television screen. In addition to avoiding large painful access wounds, the instruments used for dissection are small and fine, and thus the tissue trauma inherent to surgical dissection is reduced further. The operation is carried out with minimal trauma inside the closed confines of the respective body cavity, with avoidance of exposure, cooling, dessication, handling and forced retraction of internal organs. Thus the overall traumatic assault on the patient is curtailed drastically, and, as a result of this, recovery and convalescence are markedly accelerated. This is the most important benefit of the new approach and far outweighs the diminished cost of hospital treatment by ES which has been overemphasized. The real benefit to the individual and the nation as a whole stems from the early return to work or full activity by the vast majority of patients following treatment by ES procedures.

There are additional advantages which impart undoubted benefit. There is virtual abolition of all wound-related complications, early and late. When one considers that the average extra cost of an infected laparotomy wound is £1500, the cost saving, apart from diminished morbidity, by the avoidance of significant abdominal wounds is substantial. Likewise, the abolition of postoperative wound dehiscence (burst abdomen) and large incisional hernias, particularly in obese patients, constitutes a real and significant advance.

Another important advantage of ES which has been overlooked is the vastly reduced contact with the patient's blood during the course of the operative procedure. The importance of this in relation to transmission of viral disease such as hepatitis B and AIDS is real in terms of increased safety of the attendant staff.

There are other perceived advantages of ES. These include a reduction of the common postoperative complications associated with recumbency and pain, such as postoperative pulmonary collapse, chest infections and deep vein thrombosis. Although probable, the reduction in the incidence of these postoperative complications remains to be confirmed by prospective clinical trials. Several endoscopic surgeons, including the authors, have observed from their experience that adhesion formation is greatly reduced by ES. Other than the avoidance of a large wound, the factors responsible for this effect remain conjectural at present, and indeed the clinical impression of reduced adhesion formation needs to be confirmed by prospective studies.

Nomenclature

The editors Cuschieri and Buess have been working in close cooperation since the international congress in Berlin in 1987 on technical development, animal experimentation and clinical practice relevant to the whole field of endoscopic surgery. Our basic positions in theory and in the practice of the new surgery are essentially similar as evidenced by our contributions (often joint) in this book. Both of us have had a significant input into the new surgery and had been working in the field for several years before the boom started. There is only one disagreement between us, and this relates to the *terminology* which best describes the attributes of the new surgery. On this issue we respect each other's viewpoint and agree to differ. For this reason we had to search for a compromise, and this requires some explanation.

Buess had for years advocated the term *endoscopic microsurgery* to differentiate the new surgical techniques from other endoscopic procedures such as snare resections of penduculated polyps. However, this terminology failed to gain acceptance by surgeons who at the time failed to appreciate its significance in delineating a new era of surgical practice. The term *minimally invasive surgery* (MIS) coined by Wickham and Fitzpatrick was, by contrast, rapidly accepted by the medical and lay public and is now in widespread usage.

Cuschieri thinks that this terminology is inappropriate because it conveys the wrong meaning. In the first instance, it carries connotations of increased safety, which is incorrect because there is no correlation between "invasiveness" and risk, apart from the fact that "to invade" is absolute *(Oxford English Dictionary)* and thus cannot be qualified. Semantic considerations apart, the most important argument against the use of this terminology is that it fails to convey the essential attribute of the new approach – the reduction of the trauma of access. It is for this reason that he favours the alternative term *minimal access surgery* (MAS).

Buess favours the MIS terminology and has advocated its use in Germany. He argues that the two other terms are technically oriented, and patients do not appreciate their significance. By contrast, MIS carries beneficial psychological connotations which allay the fears of patients that operations invade the body and destroy its integrity. Buess also considers that the expression is semantically acceptable as the smaller incisions reduce the operative trauma and thus the invasiveness of the procedure. Another argument against the use of MAS in German is that *minimal access* *surgery* cannot easily be translated into German, whereas MIS can: *minimal invasive Chirurgie* and the corresponding abbreviation, MIC, is ideal.

Scope of ES

ES spans a wide spectrum of the existing surgical specialities and involves several approaches:

1. Laparoscopic
2. Thoracoscopic
3. Endoluminal
4. Perivisceral endoscopic
5. Intra-articular joint surgery
6. Combined

Laparoscopic Surgery

Laparoscopic surgery has been the most significant advance in general surgery in recent years. There is little doubt that laparoscopic cholecystectomy will become the standard method of treatment of gallstone disease applicable to over 90% of patients (see Chap. 16). Several other abdominal procedures can be performed laparoscopically, and these are described in Part III of this manual. No doubt, with improvement in instrumentation and ancillary technology, other open abdominal procedures will be performed laparoscopically in the near future. It is important, however, that surgical principles established over several decades of surgical practice are not violated in the quest for conversion to the laparoscopic approach. Regrettably, in the eagerness to be there "first", there is evidence that this unsatisfactory practice has occurred, albeit to a limited extent. Although a commitment to the development of our craft underlies its future viability as an important treatment modality, the welfare and safety of our patients must always remain paramount and at the forefront of our considerations.

Thoracoscopic Surgery

The benefits accruing from the avoidance of a thoracotomy by the established thoracoscopic procedures are even greater that those derived by laparoscopic surgery. The various thoracoscopic procedures which are currently performed in a number of centres are outlined in Part II. It seems likely that all operations on the oesophagus, resective or otherwise, will be conducted thoracoscopically in the near future. Likewise, open surgery for patients with recurrent pneumothorax will be superseded by the new approach. Presently, a number of centres are developing techniques which will permit safe limited pulmonary resections, such as removal of specific bronchopulmonary segments.

Endoluminal Surgery

Endoluminal surgery is applicable to the upper and lower reaches of the gastrointestinal tract which are accessible to the endoscopic approach. Both fibre-optic and rigid telescopic approaches can be used. Examples of the former include endoscopic sphincterotomy and, more recently, endoscopic mucosectomy for early gastric cancer. Transanal endoscopic microsurgery, which has opened new therapeutic possibilities for the treatment of rectal lesions and rectal prolapse, is covered in Part IV.

Perivisceral Endoscopic Dissection

This approach differs from the previous ones in that dissection is conducted within loose areolar tissue planes in the absence of a natural cavity. The dissection entails creating the space for visualization of the organ which is then mobilized, under vision, from the surrounding structures and organs. Examples of this technique include retroperitoneal surgery for denervation procedures, such as lumbar sympathectomy and nephrectomy, and visually controlled endoscopic dissection of the oesophagus (see Chap. 12).

Combined Approaches

There is little doubt that the future lies in the use of combined approaches: ES combined with open surgery and combined ES interventions. Currently the former is used to perform oesophagectomy with cervical anastomosis. The oesophagus is dissected either via the mediastinal route through a cervical incision using the operating mediastinoscope or thoracoscopically through the right pleural cavity. The gastric mobilization is undertaken using the standard open abdominal approach. Following resection and removal of the oesophagus and tumour, the stomach or gastric tube is pulled up into the neck by a guiding tube, and the cervical anastomosis between the proximal oesophagus and the stomach is then performed.

As an indication of the potential scope of combined ES, the equivalent of a standard three-stage oesophagectomy has been undertaken endoscopically in the pig. The cervical oesophagus was mobilized through a neck incision, the thoracic oesophagus was dissected from the mediastinum endoscopically and the stomach was skeletonized laparoscopically with preservation of the right gastroepiploic vessels. Similar combined approaches for colonic resection are currently being evaluated in the animal model.

Disadvantages and Limitations of ES

It is appropriate to consider the limitations and hazards of the new approach since, like all advances in clinical practice, ES has created new problems which have to be addressed by the profession. Some emanate from the remote nature of the surgical manipulations. In this context, the lack of direct handling of tissues with the loss of tactile feedback, which is so important to the surgeon in the evaluation of the local pathology and orientation, is obvious. There are ways around this problem, such as the development of "tactile" exploratory ultrasound probes. It is difficult to predict to what extent this will redress this basic disadvantage. Another, more serious problem is intra-operative arterial bleeding, as haemostasis is difficult to achieve endoscopically because the bleeding point often retracts within surrounding tissues. As an index of its significance, bleeding was found to be the most common cause for elective conversion to the open procedure during laparoscopic cholecystectomy in a recent audit from several major European centres. Apart from the risks of hypovolaemia, bleeding during ES considerably obscures the field of vision due largely to light absorption by the extravasated blood.

In general, procedures performed by the new approach require more technical expertise and are slower to perform, especially when one takes into consideration the setting-up time. This has important consequences on our routine practice in terms of operating sessions and scheduling of patients. The longer operating time relates, in particular, to the execution of difficult cases. Thus, for example, although the extra time needed to execute a straightforward laparoscopic cholecystectomy may be inconsequential, a difficult gallbladder (contracted organ with foreshortened cystic pedicle) often takes twice as long to complete laparoscopically when compared to the standard open operation. There is obviously a need for preoperative tests which predict the ease of performance or otherwise of a particular endoscopic operation.

There is another consequence of the execution of "difficult endoscopic operations" – increased iatrogenic intraoperative injury. This is exemplified by the higher incidence of bile duct damage during laparoscopic cholecystectomy which in some countries has risen to four- to sixfold higher than that following open cholecystectomy. It is difficult to be certain of the exact reasons for this unsatisfactory state, but it seems likely that different factors have operated in different centres. One suspects, however, that lack of training, poor clinical judgement and the use of inappropriate technology such as laser to cut the cystic duct and dissect the gallbladder have been foremost amongst the causative factors. In embracing the new approach, surgeons must accept the principle that the elective conversion to the equivalent open procedure must not be regarded as a "failure", but as an indication that in that particular patient open surgical intervention was the appropriate form of treatment. The outcome of such positive common-sense deliberations is far better than that which follows persistence with the endoscopic approach in the face of technical difficulties which often dictate open intervention several hours later when iatrogenic damage has been enacted, or worse still, when it declares itself in the postoperative period.

One of the real problems intrinsic to extirpative surgery by the ES approach is organ extraction. In some instances, use is made of natural pathways such as the mediastinum for the oesophagus and rectum for the colon. In all other situations, however, the problem remains unresolved. There has been a suggestion and indeed some are advocating methods designed to "morcellate, mince or liquidize" the organ to enable its removal. This is an ill-conceived concept which violates some of the fundamental principles of surgical management since detailed examination of the resected specimen is essential for subsequent treatment and follow-up of the patient. In the context of cancer treatment, this practice, by precluding histological staging of the tumour, would be tantamount to malpractice. In our view, intact organ retrieval is one of the most important limitations of ES, and until it is resolved, laparoscopic surgery for cancer will be restricted largely to staging lymphadenectomy for urological and pelvic neoplasms.

Future Developmental Needs

There are three major developmental needs. The first concerns the future practice of ES. Some operations such as laparoscopic cholecystectomy and appendicectomy will probably be performed by most general surgeons after suitable training. More complex and exacting endoscopic procedures are, however, best performed within specialist centres, and, in our view, there is a need for the recognition of a new surgical speciality of ES. How this would interact with the existing major specialities is the key problem. The most sensible approach would be its integration within these major specialities, e.g. thoracic and thoracoscopic surgery, colorectal and endoluminal surgery, etc.

Following from the above, there is a need for training programmes both for general surgeons and for experts in the new speciality. Some of these issues are addressed in Chap. 6. Finally, the present instrumentation and technology require development to facilitate and improve the safety of remote surgical manipulations carried out under endoscopic vision. The important requirements in this field are outlined in Chap. 27.

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2 Instruments for Endoscopic Surgery

A. MELZER, G. BUESS, and A. CUSCHIERI

Introduction

ES is characterized by the small size of a number of access ports. Working in a low-pressure gas environment requires the instrument shafts to be round to maintain an airtight seal which restricts mechanical construction. The small diameters also mean that very high-quality materials are necessary to avoid frequent instrument failure. The video systems, light sources, insufflators, and accessory instruments are technically complex, and the ES surgeon has to understand the technology of the equipment to appreciate its use and future development.

Basic Requirements of the Instruments for the ES Surgeon

Sterilization

All instruments and devices introduced into the body must be completely sterilizable. One of the most reliable methods is the steam autoclave. However, this causes severe stresses on the instruments, which have to be made of materials resistant to corrosion despite repeated exposure to a saline environment. In addition, when used in combination, materials have to be carefully manufactured to allow for different expansion properties. This is especially important with optical systems. The requirement for sterilization of instruments entails direct contact of organisms with steam or gas. Therefore instruments must be completely sealed to prevent entry of blood and body fluids, or they must be capable of being dismantled and cleaned.

The use of disposable instruments has to be carefully evaluated from the point of view of expense and ecological aspects.

Radiolucency

Improvement of metal instruments by the use of radiolucent materials is required. During surgical procedures using X-rays, metal instruments (e.g. cannulae) may mask important anatomical areas of interest. Stainless steel clips distort radiological images and occasionally impair their interpretation. However, it is not at present feasible to manufacture all these instruments from radiolucent materials (e.g. ceramics or plastics).

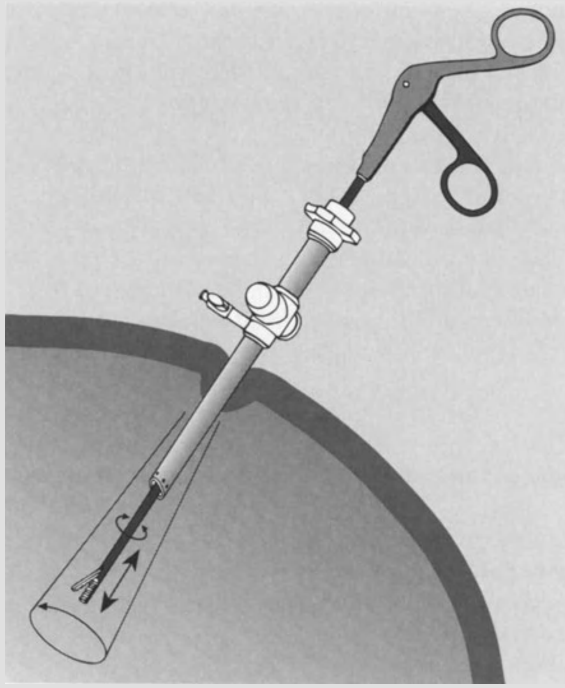
Light Reflection

Highly polished metal surfaces facilitate cleaning. However, this reflecting surface disturbs the operation. The automatic light sensor of the chip camera reacts to these reflections by darkening the view on the video screen. By using matt instrument surfaces, it is possible to decrease light reflection, but this increases the susceptibility of the metal to corrosion.

Ergonomics

The improvement of specialized instrument function requires the use of ergonomic principles. In laparoscopic surgery the ergonomic principles are different from those in conventional surgery:

1. The instrument handles must function independently of the rotation of the instrument tip.
2. All functions of the instrument must be capable of being carried out with one hand.
3. The jaws of the instruments must be angled to allow adequate visibility of their tips. While the jaws are closed, the shaft of the instrument should not require movement to keep the position of the jaws constant.
4. Clip applicators should have a cartridge containing the clips.



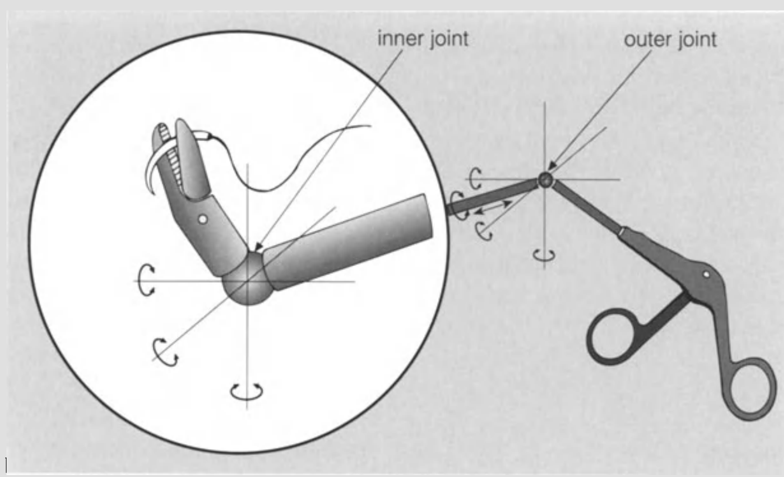


Fig. 2.1. **a** Dimensions of freedom of a conventional instrument in ES. **b** Concept for a new endoscopic needle holder showing three dimensions of increased freedom. Every movement of the handle is transmitted to the tip of the instrument by the inner and outer ball joints

Degrees of Freedom

The concept of degrees of freedom describes the ability to move instruments within the operative field. Present laparoscopic instruments have two to three dimensions of freedom (Fig. 2.1 a):

1. Translation – the movement of the instruments in the direction of their longitudinal axis.
2. Axial rotation – rotation of the instrument around its longitudinal axis.
3. Relative rotation around the entry point – this is the rotation of the instrument tip within the operative field around the point of entry (e.g. cannula or instrument channel). This dimension of freedom is not constant but depends on the type and size of access port.

In the future, increasing the number of dimensions of freedom could be achieved by introducing controllable ball-and-socket joints into the shaft. Every movement of the handle would then be translated to similar movements of the inner ball-and-socket joint (Fig. 2.1 b). Such an instrument would function along the lines of a mechanical remote-control grasper. The early models will need to be easy to handle in the interests of safety. By careful stepwise evolution, future developments could encompass computerized robot-controlled systems. At present these are routinely used in advanced industrial applications (see Chap. 26).

Dissection Techniques and Combination Instruments

Dissection during laparoscopic surgery requires a minimum of three functions: haemostasis, cutting and suction. At present, these functions require multiple instruments, e.g. to cut a vascular pedicle it is necessary to coagulate it first and then to change instruments to transect it. This is clumsy and time consuming because of the long shaft of the instruments. Heavy bleeding from a transected vessel has the added tendency to obscure the lens of the optic. Suction to reveal the precise point of bleeding usually requires a change of instruments. This problem can be solved by a combination of the single functions within the same instrument or the development of new dissecting systems, e.g. the combination of a coagulating with a cutting function to allow a wide coagulation field and a narrow central cutting zone. Both systems were developed in Karlsruhe and Tübingen and are currently undergoing testing.

Automated Operating Techniques

Compared to open suturing and knotting, endoscopic techniques are clumsy and time consuming, and require refinement. The circular stapler used in conventional surgery and automatic ligature devices are not yet available for use in laparoscopic surgery. A linear stapler (Endo GIA, Autosuture) is now available for clinical use in Europe. The extracorporeal and internal instrumental knotting methods are slow and clumsy for placement of interrupted sutures. The Roeder knot should only be used with catgut as only this material swells significantly during hydration, so increasing knot security. New techniques under development at Tübingen include slip knots usable with polydioxanone (PDS), a bioabsorbable clip and an automatic ligature system. In close cooperation with the Nuclear Research Centre Karlsruhe a semiautomatic sewing device will allow refinement of endoscopic sewing techniques.

Ancillary Technology

The delivery of light, video images, suction, irrigation and coagulation have to be refined. One of the important aspects in development is to improve remote control and adjustment of the devices while keeping them as simple as possible. At present, the surgeon and operating room team are often required to use up to 100 switches and adjustment controls. Combination of single- and multiple-function controls into a central remote control console would help considerably.

Systems Presently Available

Optical Systems

Endoscopes are by definition thin and rigid, semiflexible or flexible. They may be introduced into the human body through natural orifices or access ports created for this purpose, allowing direct visual inspection. The main problems with image transmission are the narrow calibre of the optics and long length of the endoscopes. High light intensities are required to obtain the correct colour of the visual image, especially for video reproduction. The light sources are fixed externally, and light is normally delivered via glass fibre bundles. On account of spacial restrictions, only one source of light is used. Good image quality depends on clarity, correct colour and high resolution (that is, very small distances between individual points). Good image light transmission through lenses (F number) is achieved in the photographic lens by a large lens size and correcting lenses. In addition, further improvement is possible by using high-quality manufacturing processes to coat the lens surface. Because of the very small size of endoscope lenses (down to 0.3 mm in diameter) and the requirement for multiple lenses, very stringent manufacturing standards are required to approach the quality of the standard photographic lens: multiple lenses each possibly having insignificant flaws may, however, cause image distortion in combination. At present it seems that further dramatic improvement in modern rigid endoscopes is not likely to occur. This is not a problem at the moment because the chip video cameras currently used in ES have resolutions lower than endoscopic optics.

Flexible endoscopes use glass fibre bundles for image transmission, and presently these approximate to the resolution of chip video cameras. Further improvement in standard flexible endoscopes is limited by current technological factors, but dramatic improvement may be realized in the next few years in flexible endoscopes using a charge-coupled device (CCD) at their tip for image transmission.

Rigid Monocular Endoscopes

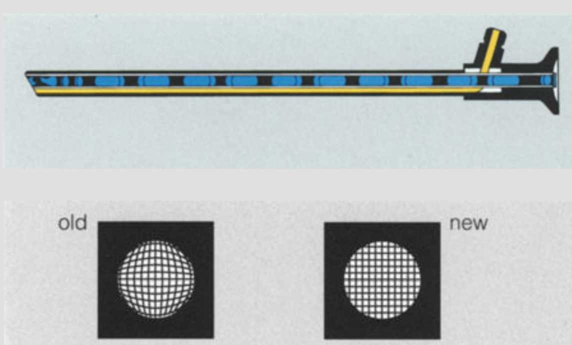
Basic Technology of Rigid Endoscopes

At the distal end is a front lens complex (inverting real-image lens systems, IRILS) which creates an inverted and real image of the subject. A number of IRILS (dependent of the length of the endoscope) transport the image to the eyepiece containing a magnifying lens. In the Hopkins rod-lens system, light is transmitted through glass columns and refracted through intervening air lenses (Fig. 2.2a). The transmission of light, colour definition and quality of the image was greatly improved by this design. The front lens of an endoscope varies with an opening angle from 67° to 12°, similarly to photographic wide-angle lenses. At the edges of the image, distortion occurs in a similar way to a fish-eye effect (Fig. 2.2b). In the new generation of endoscopes from Olympus, Winter and Ibe, this fish-eye distortion is partially corrected by compensation lenses (Fig. 2.2b).

At a certain distance from the front lens (also dependent on the opening angle), there is the neutral distance of the system, i.e. objects at this point appear 1:1 relative to their actual size. By closer approximation to the front lens, objects are magnified while viewing from further away results in them appearing smaller; the endoscope does not simply magnify the image as does a microscope.

Rigid Monocular Optics Currently Available

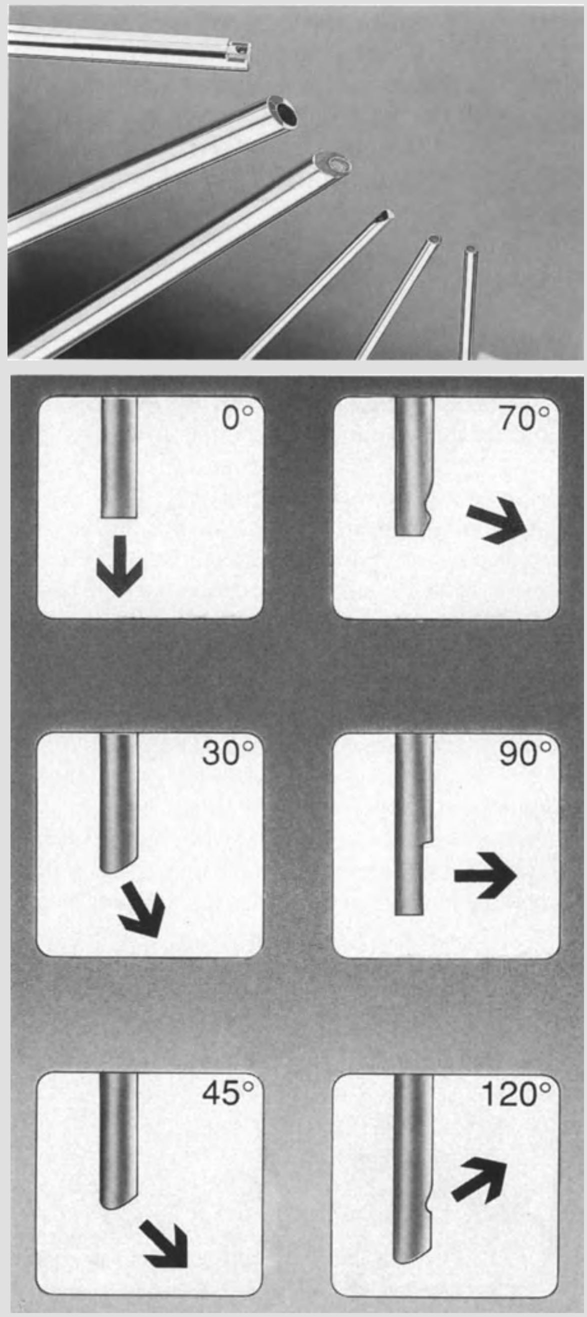
Depending on the surgical function, there is a choice of various endoscopes (Fig. 2.3a). Diameters range



a

b

Fig. 2.2. **a** Longitudinal section of modern rigid endoscope (Panaview, Wolf). Light is reflected at the surfaces of air lenses and transmitted in glass rods. **b** Distortion of the borders of the image through the endoscope; *old*, conventional lens system; *new*, new lens system using image correction lenses (Olympus, Winter & Ibe)



a

b

Fig. 2.3 a, b. Rigid endoscopic optics (Olympus, Winter & Ibe; Storz; Wolf). **a** A range of different rigid endoscopes; **b** various viewing angles from 1.9 mm to 14 mm, with varying viewing and opering angles. The spectrum of viewing angles ranges from 0º forward-viewing, 30º forward-oblique, 45º oblique, 70º oblique up to 120º reverse-viewing (Fig. 2.3 b).

A 30º–60º viewing angle is, in our opinion, useful during laparoscopic surgery. It allows forward viewing in combination with lateral viewing by rotation of the endoscope about its long axis. More acute viewing angles are not advisable either for diagnostic or therapeutic endoscopy due to frequent mistakes in orientation. Operations using single access ports require endoscopes containing a working channel: e. g. endoscopic microdissection of the oesophagus (see Chap. 9).

Stereoscopic Optics

Stereoscopic optics allow depth perception within the operative field. This is achieved by the integration of two monocular optical systems and two eyepieces adjustable for the separation of the surgeon's eyes.

Development of Stereoscopic Optics

The first stereoscopic optic was made in 1904 by Loewensteins for cystoscopy, using ideas developed by Jacoby. Modern stereoscopic endoscopes are based on this construction. In 1980 a new stereoscopic endoscopic system was presented by Jonas for tumour resection in the bladder and prostate. We started with the development of stereoscopic optics for transanal endoscopic microsurgery (TEM) in 1980.

Basic Technology of Stereoscopic Optics

The stereoscopic optic for TEM (Wolf) has two parallel integrated rod-lens systems 6.3 mm apart, with a 50º oblique-viewing angle and a 75º opening angle transmitting images seen by the viewer as a three-dimensional picture. Image transmission is made possible by using a system of prisms, and the eyepieces are adjustable over a distance of 56 mm–72 mm to match variation in the distance between the surgeon's eyes (Fig. 2.4).

The endoscope has an integrated lens-washing system and central channel of 6.7-mm diameter to convey a monocular optic connected to the video camera.

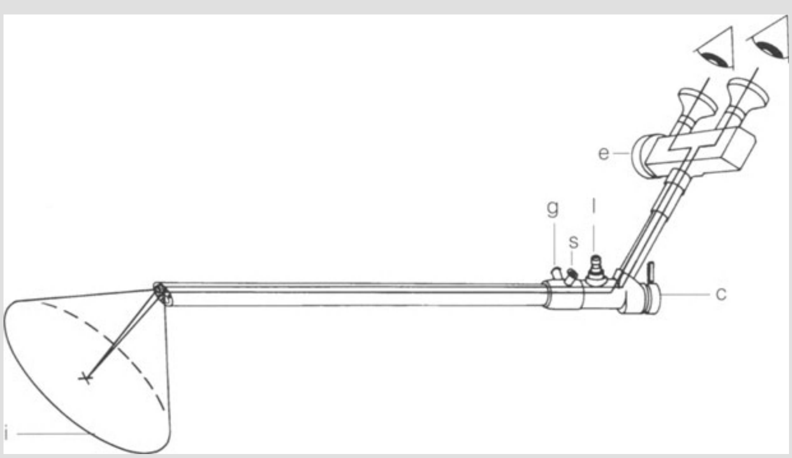
Flexible and Semiflexible Endoscopes

Flexible endoscopes have an eyepiece similar to rigid endoscopes: however, the image transmission is either by oriented glass fibre bundles or electronically by the distally sited CCD.

Development of Flexible Endoscopes

Based on the effect of light transmission discovered by Thyndal in a waterjet, in 1905 Baird showed light transmission in glass columns. Lamm attained the first practical use of glass fibre bundles by combing them. In 1932 Wolf and Schindler made the first semiflexible endoscope by using movable connected IRILS (see *Basic Technology of Rigid Endoscopes* above) in a flexible tube. But it was only when standardized industrially manufactured glass fibres became available that in 1958 Hirschowitz, Peters and Curtiss presented the first fully flexible endoscope.

Fig. 2.4. Principles of light transmission in the stereoscopic lens system (Wolf). *e*, Adjustable eyepieces; *i*, stereoscopic image; *c*, channel for the teaching optic; *l*, connection for the light source; *s* connection for the lens-cleaning system; *g*, connection for gas insufflation



Basic Technology of Flexible Endoscopes
The flexible tips of the endoscopes are controlled proximally by hand controls. This distal movement is in two planes with the wider-diameter endoscopes, but only in one plane with the smaller endoscopes. It is achieved by cables which are carried within the body of the endoscope along with optic fibre bundles, light transmission fibre bundles, a washing channel to clean the lens and a working channel (Fig. 2.5).

The image transmission in flexible endoscopes is either performed by oriented glass fibre bundles or a distally placed CCD (Fig. 2.6). This chip has light-sensitive pixels, up to 400000 in number. These pixels convert the incoming light into electrical impulses which are read serially line by line at a certain frequency and then transformed and saved to create a video image. There are different ways to create a colour image: either the pixels are activated through a mosaic colour filter or through a rotating filter of the primary colours.

In modern standard flexible endoscopes, up to 40000 glass fibre bundles convey the image. These fibres require exact orientation: i.e. the position of the fibre at the distal end is the same when it reaches the eyepiece. An increase in the number of fibres impairs the flexibility of the endoscope. The best fibres are each less than 7 μm in diameter, and further decreases in this diameter, although desirable, are at present not possible below 6 μm. There are three different types of glass fibres. These are: *glass fibres, gradient fibres* and *quartz fibres.*

Glass Fibres. The single glass fibre has a centre of glass and an outer glass sleeve. This outer glass has a lower light diffraction index. When a light beam passes up the central glass fibre, it is totally reflected upon contact with the outer coating glass sleeve because of its different diffraction index and it is therefore transmitted up to the end of the central glass fibre (Fig. 2.7).

Gradient Fibres and Quartz Fibres. In very thin endoscopes, gradient fibres and quartz fibres are used for light transmission. In the gradient fibres the light diffraction index changes continuously from the centre towards the outer surface and not as a sudden change, as occurs at the coating of the glass fibres.

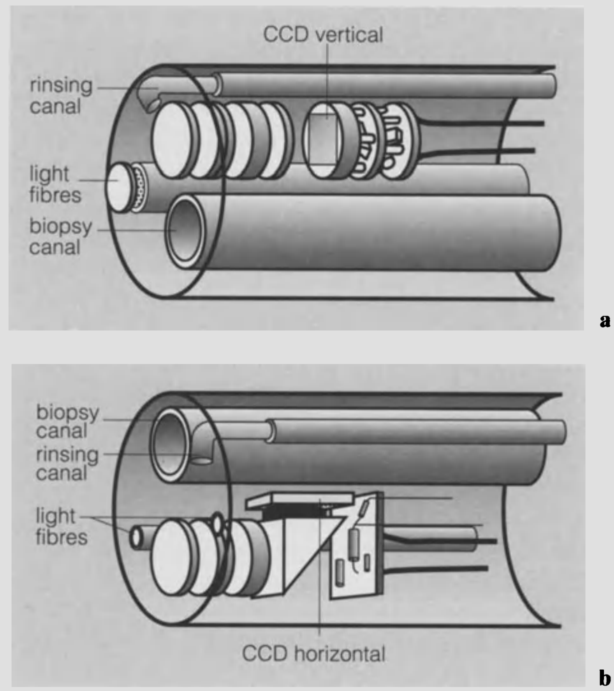


Fig. 2.6 a, b. The integration of the CCD chip into the tip of the endoscope. **a** Olympus, CCD vertical; **b** Fujinon, CCD horizontal

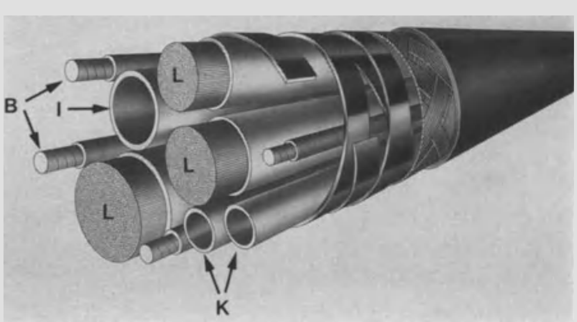


Fig. 2.5. Transverse section of a flexible endoscope (Olympus). Glass fibres convey light in and the image out *(L)*. Suction and irrigation channels *(K)*. Working channel *(I)*; *B*, steering cables

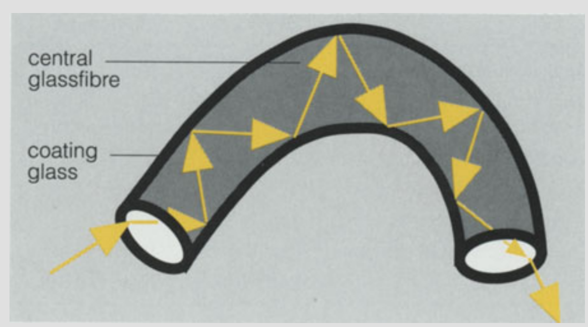


Fig. 2.7. Light passing through a glass fibre. On account of the lower diffraction index of the coating glass, the light is totally reflected

However, a complication in the present manufacture of this type of fibre is that the spectrum of the transmitted light alters. Quartz fibres consist of single fibres melted together, resulting in improved image quality compared to glass fibres.

Surgical Requirements for Optical Systems

Table 2.1 shows the properties of endoscopes required in surgery and compares flexible and rigid endoscopes. Further improvement of glass fibre endoscopes is at present limited. In contrast, the CCD chip and video-imaging techniques have a large scope for development (megapixel chip). It can be foreseen that in the near future the quality of the rod-lens system could be approached. In ES three-dimensional imaging is urgently required, but this is presently only available with the TEM endoscope (Wolf 1979). However, on account of its adjustable eyepiece, this endoscope is only sterilizable using ethylene oxide gas. Improvement here is possible by connection of two chip cameras to obviate the need for adjustment of the eyepiece, and to create a three-dimensional image on video screens. Owing to new construction methods and secure sealing combined with matched thermal response of the different materials (glass, plastic and metal), monocular endoscopes are autoclavable (Olympus, Winter and Ibe).

On account of the materials used, it has not been feasible to manufacture autoclavable flexible endoscopes. Complete sterilization by autoclaving is highly desirable from the point of view of decreasing the risk of transmissible infection. New methods of low-temperature sterilization using H_2O_2 are under development.

Table 2.1. Ideal endoscopic requirements for the surgeon

	Rigid endoscopes	Flexible endoscopes
Small diameter	Yes	Yes
High-resolution fibres of pixels	Yes	Dependent on the endoscope
Good depth of field	Yes	Yes
Good magnification	Yes	(Yes)
A wide opening angle	Yes	Yes
Three-dimensional imaging	Partially	In experiment
Autoclavable	Partially	Not available

Light Sources

In a cold light source, light is produced either by globes with filaments or containing vaporized metal and it is transmitted down glass fibre bundles to the tip of the endoscope.

Development of Light Sources

The first device used to convey light into the body was used by Bozzini in 1790. The discovery of the light bulb by Edison in 1875 and its miniaturization in size to the mignon globe allowed its insertion within the tip of the endoscope. The good illumination achieved with this instrument made its clinical use practical. However, 97% of the electricity used was converted into heat energy and problems occurred with burn injuries. The introduction of cold light (Storz) formed the basis for subsequent endoscopy, especially in the areas of endoscopic photography and video camera applications.

Basic Technology of Cold Light Sources

The light is generated from powerful halogen bulbs or bulbs containing vaporized metal with an output of 70–400 W. The light output from these bulb filaments has to be focused onto the surface of the light-transmitting fibre bundles to achieve maximal light output. This is achieved by using a concave mirror behind and a condenser in front of the bulb. A filter lowers the heat transmission (Fig. 2.8). Parallel to this bulb, it is possible to place a flash light which by TTL connection can be synchronized with the camera (Wittmoser). Glass fibre bundles or fluid crystal light transmitters are used for light transmission between the light source and endoscope.

Glass Fibres. Light transmission occurs as described in "Basic Technology of Flexible Endoscopes" above. Only glass fibres should be used because gradient fibres do not completely transmit light in the visible spectrum, resulting in colour distortions.

Fluid Crystal Light Transmitters. Fluid crystalline substances are complex organic molecules which have a long form; in a certain phase, some degrees above their melting point, their behaviour is like hard crystals because the long molecules orient in layers within which they are able to move. This structure has light diffraction characteristics similar to classical hard crystals. The delivered light contains nearly the full spectrum of visible light. The main disadvantages in their use are the inability to sterilize these cables by autoclaving or gas and decreased flexibility.

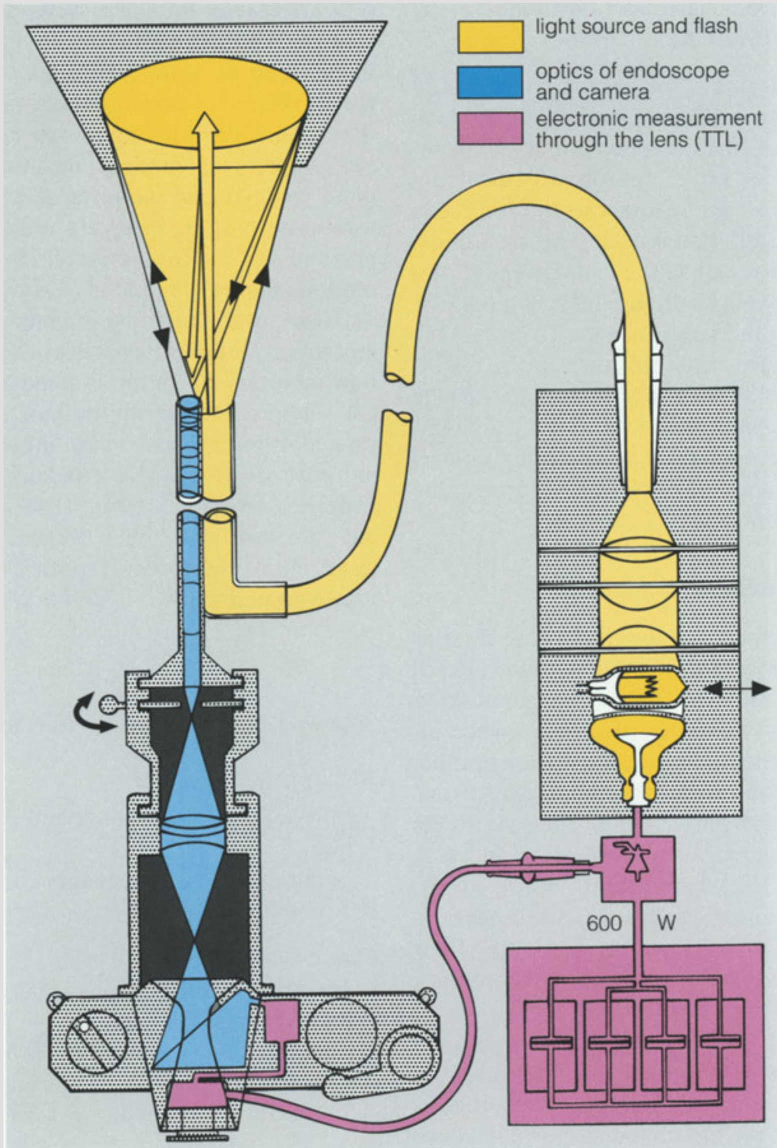


Fig. 2.8. Light source with incorporated flash, controlled in real time by the camera TTL light measurement (Wittmoser)

Surgical Requirements for Light Sources

- High light intensity
- Complete light spectrum
- Integrated flashlight for photodocumentation
- A reserve bulb
- Video camera-controlled light intensity adjustment

Adequate Light Sources and Transmitters

Output of 150 W from the light source would be enough for direct viewing down the endoscope. For video cameras, intensities up to 400 W are required. For routine clinical use, glass fibre bundles are adequate, while for high-quality documentation fluid cables and an integrated flash light are desirable.

Insufflation Devices

Principles of Exposure of the Operative Field

Basically there are two different ways to expose the operative field:

- Distraction by mechanical retraction methods
- Distension by gas insufflation

For example, during mediastinascopic perioesophageal dissection (Buess, Kipfmüller, Naruhn und Melzer), gas insufflation is not useful and exposure is provided by the "olive" pulsion tip of the endoscope. During laparoscopic, thoracoscopic and rectal procedures, CO_2 insufflation is used. The basis of exposure during laparoscopy is the establishment of a pneumoperitoneum. This is often achieved initially by blind puncture using the Veress needle. To protect the abdominal organs during this puncture, Götze (1918) and later Veress (1938) integrated a snap mechanism within the cannula. After penetration of the abdominal wall, a blunt atraumatic spring-loaded central stylet conveying the gas moves forward to protect the underlying bowel from injury.

Development of Insufflation Devices

Endoscopic developments in the nineteenth century which were able to view the abdominal organs led to the requirement of a space provided by a gas cushion within the peritoneal cavity for placement of the instruments. The first gas (air) used during long procedures caused problems with gas embolism. Nitrous oxide represents a risk from gas embolism, anaesthetic effects from rapid uncontrolled absorption and hazards to the health of the theatre staff from leaked gas. The insufflation with inert gasses such as helium or argon have some potential advantages, including their lower solubility in water which prevents condensation on the optics.

Probably the best gas for insufflation at present is CO_2. It is 200 times as diffusable as oxygen and is therefore rapidly cleared by the lungs. Pneumoperitoneum for long periods has not been shown to cause significant acidaemia (Kastendiek 1973). Lindemann (1980) showed that cardiac arrythmias and haemodynamic disturbances occurred only with direct intravascular CO_2 insufflation at rates greater than 150 ml/min. Wittmoser (1961) created a device for controlled CO_2 insufflation with an adjustable pressure limit and synchronous measurement of the filling intra-abdominal and intrapleural pressure (Fig. 2.9 a). In 1965 Eisenberg and Semm developed the Wisap-CO_2-Pneu.

Basic Technology of Insufflation Devices

Insufflation devices are used to create the intra-abdominal pressure necessary for laparoscopic exposure. Loss of gas by leakage or absorption is replaced by semi- or fully automatic systems. The gas supply is a standard CO_2 cylinder connected externally. Because of the high pressure (up to 60 atmospheres) within these cylinders, a pressure relief valve is used to lower the maximal insufflating pressure. In contrast to earlier devices, in modern insufflators, an intermediate gas cylinder requiring manual refilling is not used. The refilling rates are now automatic up to a maximum of 10 litres a minute. The front of the device has four gauges to monitor CO_2 cylinder pressure, the maximal intra-abdominal pressure, the gas flow rate and total volume of gas delivered. The electronic system monitors the intra-abdominal pressure via the CO_2 supply line by intermittent interruption of gas flow, allowing accurate recording of the intra-abdominal pressure (Fig. 2.9 b). This electronic system controls the rate of gas flow until the preselected abdominal pressure has been reached. During initial insufflation prior to visual control, the maximal rate of flow is limited to 1 litre a minute at a maximal pressure of 10 mmHg.

Surgical Requirements for Insufflation Devices

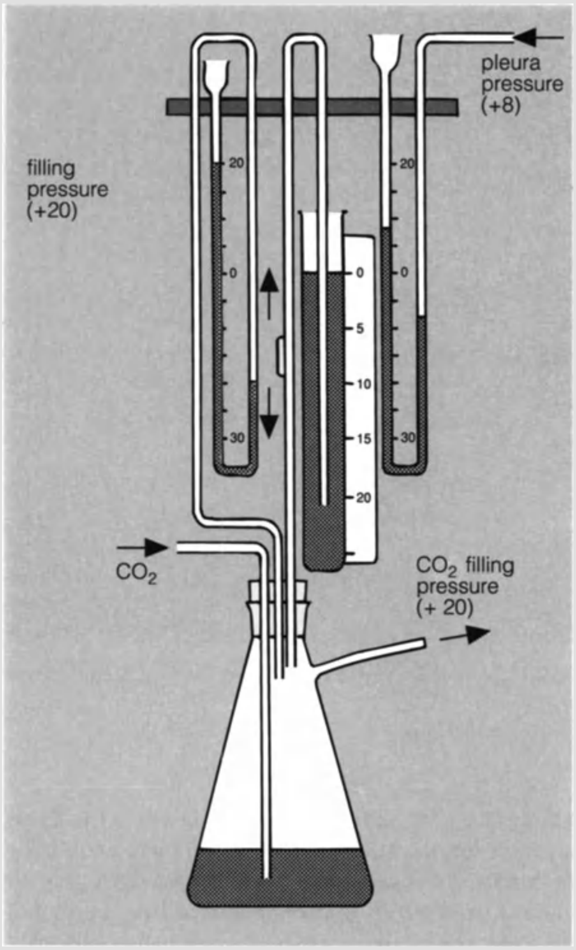
Presently Available
- Limitation of the amount and pressure of insufflation
- Maintenance of a constant pneumoperitoneum
- Automatic electronic control systems

Future Developments
- Audiovisual warning for all malfunctions
- Readable analogue gauges
- Combination of controls for suction and insufflation within a single device
- Simplicity of handling

The insufflation devices available, depending on the model used, have integrated flow and pressure control systems. The surgeon buying these devices should choose a model with audio malfunction alarms.

Aspiration and Irrigation

During ES bleeding and its control are very important as blood may rapidly obscure endoscopic vision. Conventional surgery makes use of suction and absorptive abdominal packs to stop bleeding. But in endoscopic surgery the use of swabs and the power of the suction is limited. The power of the sucker is limited by small tube diameters and long length. In addition, high suction rapidly leads to loss of pneumoperitoneum and



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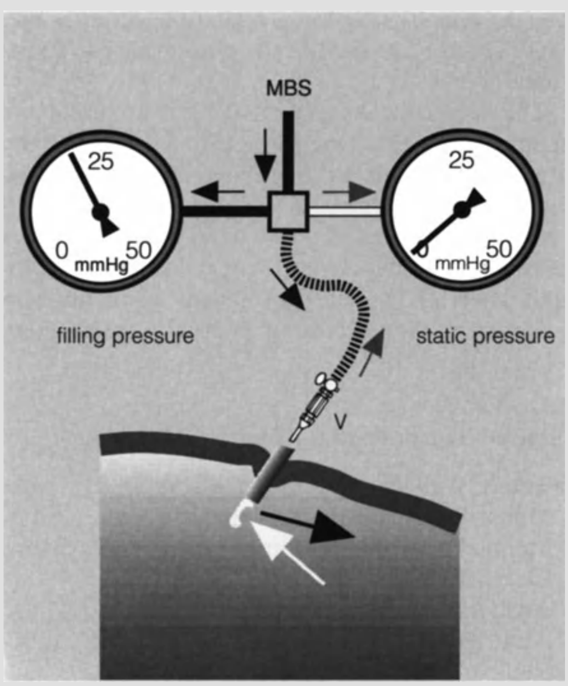


b

Fig. 2.10. Irrigation and aspiration. On the *right* is the irrigation reservoir and on the *left* the suction bottle

endoscopic view, which is only preventable by insufflation at higher flow rates which would be best achieved by monitoring the volume aspirated allowing controlled replacement.

Surgical Requirements for Aspiration and Irrigation Devices

Presently Available

- Adjustment of aspiration and irrigation rates
- Hand controls on the instrument

Future Developments

- Automatic control of aspiration and irrigation rates
- Separate channels for the irrigation and suction
- Larger irrigation fluid reservoir
- Audiovisual malfunction alarms

Advantages and Disadvantages of the Different Designs of Aspiration and Irrigation Devices

The modern aspiration/suction devices have a handle with two valves as controls (Fig. 2.10). The trumpet or cylinder valves are robust and seal despite contamination of the lumen by blood or tissue, but valve movement may be impaired by trapped blood and occasionally jam. The easy-to-use tube clamps in the Wisap handle avoid blocking, but there is a risk of fatigue and

Fig. 2.9. a Principles of an insufflation device first developed by Wittmoser with measurement of filling pressure and intrapleural pressure. **b** Monofil bivalent system (Semm). Using the Veress needle *(v)*, it is possible to measure the filling and abdominal pressure by interruption of flow

breakage of the silicon tubing. The three-way valve model manufactured by Wolf seems to go some way towards solving these problems.

The reservoir of the irrigation liquid normally contains 1 litre sterile physiological NaCl solution. This amount is enough for the average procedure, but if large irrigation volumes are required, a larger reservoir is desirable. An audiovisual alarm to indicate the need to refill this reservoir would be helpful. The suction bottles should be at least twice the capacity of the irrigation reservoir to accommodate blood, body fluid and froth to avoid frequent interruption of suction to change them. With the combination of irrigation, aspiration and insufflation, controls using a central console would then be possible.

Trocars and Cannulae

In laparoscopic surgery the trocar is introduced into the cannula to accomplish cannula penetration of the abdominal wall. The cannula has a valve system at its proximal end, and the trocar is removed from the cannula after puncture of the abdominal wall. The cannula acts as a channel for the introduction of the endoscopes and instruments. The autoclavable, re-usable systems normally employ cylinder or trumpet valves. Ball or flap valves are used in re-usable cannulae up to 7 mm in diameter and in disposable devices. The distal end of the cannulae is either cut obliquely or at a right angle (Fig. 2.11)

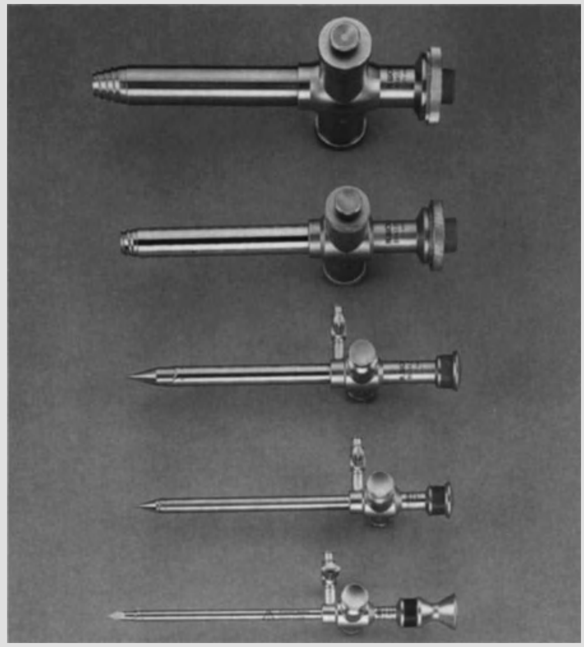


Fig. 2.11. A range of various trocars and cannulae from 5 mm to 20 mm

Trocars and cannulae are available from 3 mm to 13 mm in diameter, and with a special dilation system this can be expanded to 20 mm (Fig. 2.12). Use of a guide rod within the original cannula allows its removal. The dilating cone is then placed within the new cannula. This combination is then fed down over the guide rod through the abdominal wall using three turns in a clockwise screwing action while exerting steady pressure. The guide rod with dilating cone is then removed.

The Hasson (1971) trocar system was specially developed for use in the open laparoscopic technique, particularly in patients having a previous laparotomy and suspected adhesions. The main advantage of this development is that the cannula can be placed under direct vision. Furthermore, no special preparation is required for this approach because the same umbilical incision as used in closed laparoscopy is necessary. The Hasson cannula is a modified 10-mm cannula with normal trumpet valve. It has an outer tube with an adjustable cone-shaped dilatation tip to maintain the pneumoperitoneum by sealing the fascial incision. Additionally, two suture wings are fixed near the trumpet valve for the attachment of fascial sutures. To keep the cannula in position and to avoid gas escape, the dilatation tip is firmly approximated to the opening of the abdomen by two sutures placed at the borders of the fascial incision and attached at the suture wings. These sutures are used in the closure of the fascial wound.

The disposable systems made by AutoSuture and Ethicon have flap valves (Fig. 2.13b) and sharp triple-edge pyramidal tips. Both systems employ a thin tube between the trocar and the cannula, which snaps forward after penetration of the abdominal wall with a delay of approximately 12–15 ms and locks in that position covering the sharp pyramidal trocar tip. This construction should prevent internal visceral injury (Fig. 2.14).

Surgical Requirements for Trocars and Cannulae

Presently Available
- Minimal trauma to the abdominal wall
- Minimal leakage of gas during instrument exchange
- Electrical insulation
- Anchorable to the abdominal wall
- Autoclavable
- Radiolucency

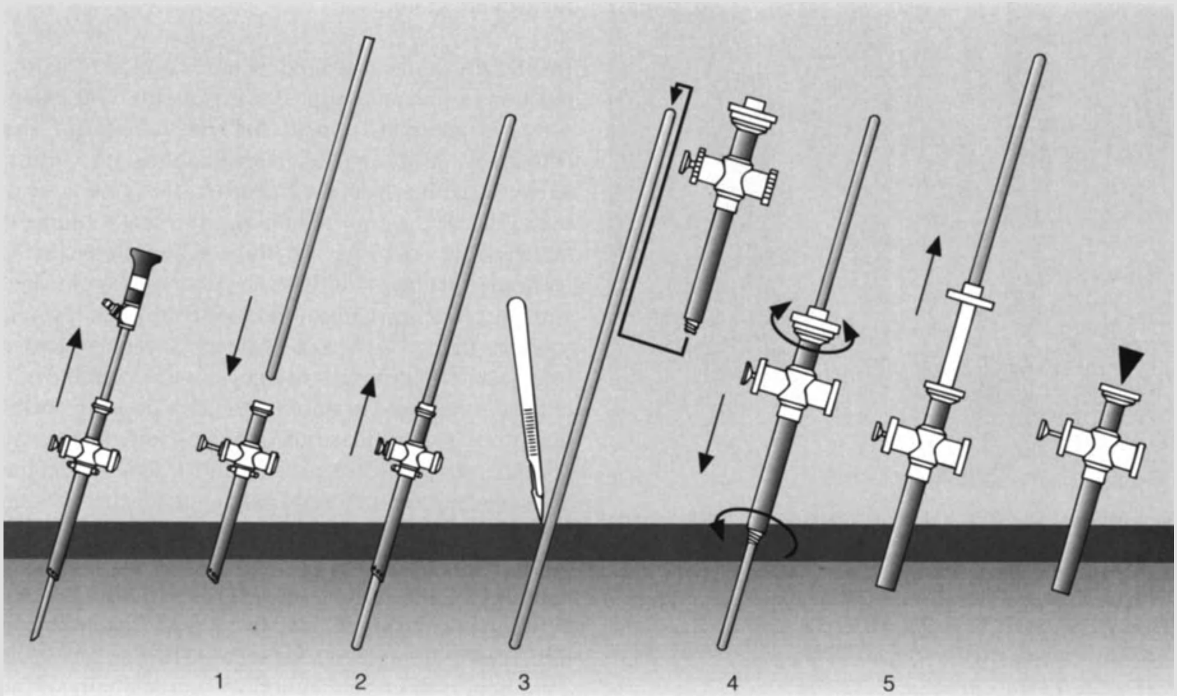


Fig. 2.12. Schematic portrayal of a 5 mm port increased to 10 mm. *1*, Endoscope is replaced by a guide rod; *2*, the 5-mm cannula is removed leaving the guide rod behind; *3*, after extending the skin incision with a scalpel, the dilatation trocar inside the 10-mm cannula is passed over the guide rod; *4*, the dilatation cannula is passed through the abdominal wall by a clockwise screwing action with steady pressure; *5*, the guide rod and dilatation trocar are then removed leaving the 10-mm cannula in place

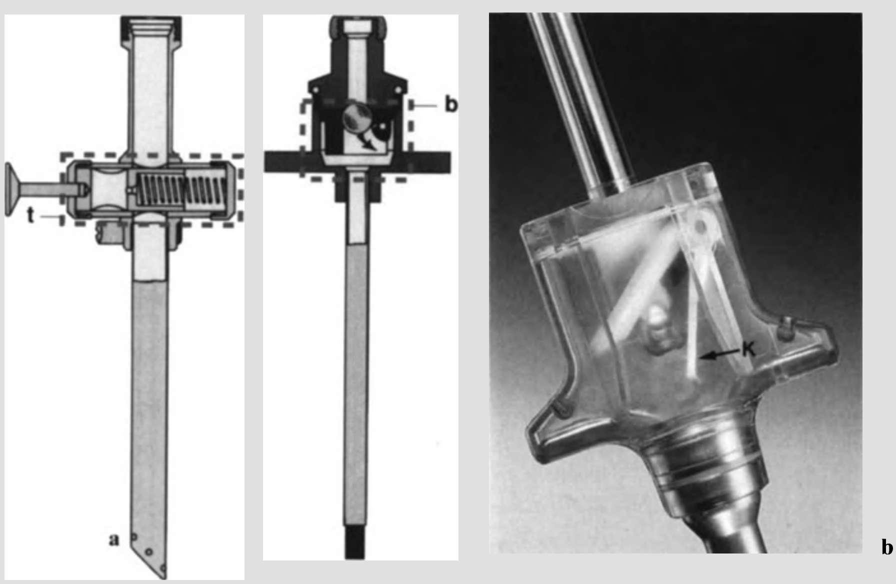
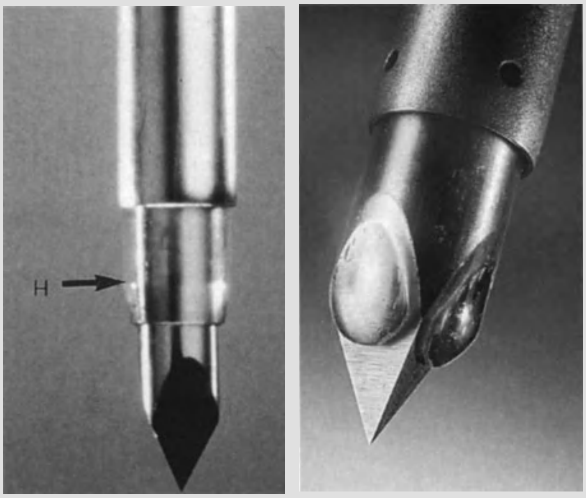


Fig. 2.13 a, b. The types of valves used for cannulae. **a** On the *left* is a 10-mm cannula with a trumpet valve (*t*). On the *right* is the ball valve of a 5-mm cannula (*b*). **b** Specially designed transparent cannula shows the principle of the flap valve (*K*) (Ethicon)



a, b

Fig. 2.14 a, b. The pyramidal sharp tips of the disposable trocar with its cannula. The "safety" shield *(H)* slips past the tip of the trocar once through the abdominal wall and should protect the internal viscera. **a** AutoSuture; **b** Ethicon

Future Developments
- Minimal force for abdominal wall penetration
- Safe and easy handling of the valve system
- Prevention of internal visceral injury
- Optically controlled penetration

Advantages and Disadvantages of the Different Designs of Trocars and Cannulae

The injury of internal viscera may be minimized by the technique used combined with the skill and care exercised by the surgeon. The atraumatic conical trocars also minimize the chance of abdominal wall blood vessel injury and gaping of the hole in the abdominal wall fascia after cannula removal (as occurs with sharp pyramidal trocars). The main advantage of the sharp pyramidal trocars is the lower force required for tissue penetration. The safety shield does not guarantee prevention of internal visceral injury, especially in the presence of adhesions (see Figs. 13.2, 13.3). A disadvantage of the disposable systems is their cost. An advantage is their perfect sterilization.

Gas leakage is prevented by trumpet, flap or ball valves (Fig. 2.13). The easy-to-use flap and ball valves may lose their gas seal in the presence of tissue contamination. Trumpet valves seal relatively well when contaminated, but then may jam more easily. The improvement of valve systems would be possible by using materials with a low friction coefficient or by redesigning them.

Instrument Holders

In ES fully adjustable holders are required to fix the position of the endoscope or instruments. One example of a good instrument here is the Martin arm (Fig. 2.15). A 15-mm diameter stainless steel rod is anchored with a special clamp to the rail of the operating table. The clamp tightening, the screw onto the table rail also locks the rod into position. Between the rod and instrument holder is a system of two knuckles and one locking hinge joint, all controlled by one screw contained in the axis of the hinge. Single-handed release and tightening is thereby possible, but the other hand is required to stabilize the new position during this process. A similar function is obtained using the Aesculap Leyla-Retractor (Fig. 2.16). This system has an arm of approximately 40 ball segments that fit within each other and are locked in position by a central cable tightened by an overcentre lever. Its ability to maintain its position arises from the friction created between the ball segements. In a new design modification, these ball segments are tapered in size, providing a gradient of friction and improving the ability of the equipment to lock in position. This instrument only functions when a low force is exerted.

A recently developed instrument, the Robotrac made by Aesculap (Fig. 2.17), is the first system allowing position control plus locking with one hand. The pneumatic locking mechanism is activated and deactivated by two solenoid switches integrated within the handle. The compressed air supply is controlled by an

Fig. 2.15. Martin arm holding an endoscope

Fig. 2.16. Leyla-Retractor (Aesculap). Central wire fixation of segments *(K)*, with locking and release controlled by an over-centre lever *(S)* and instrument fixation clamp *(H)*

external device. It seems from the dimensions of this system that it can be used with a greater force. This expensive system is not sterilizable and must therefore be covered by a sterile polyethelene tube. When deactivated the components limbs are flaccid and have to be held.

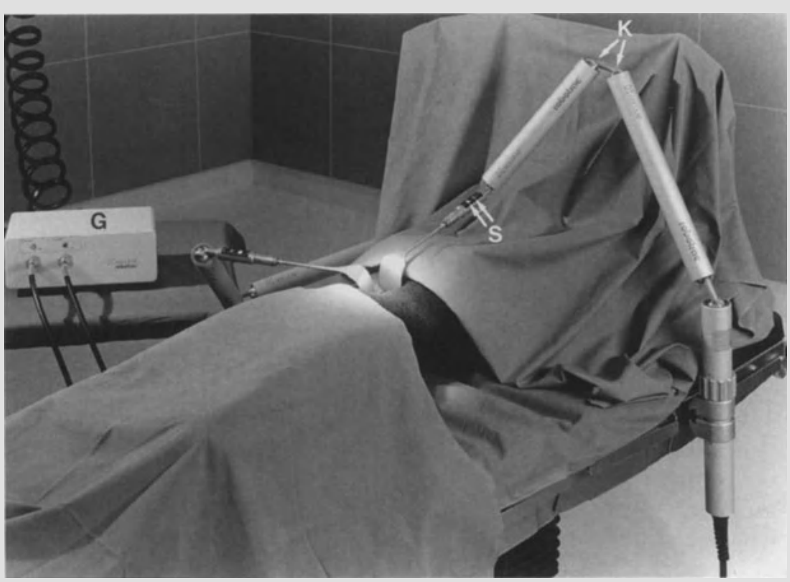
A vacuum lock holder, the First Assistant (Leonard Medical), is robust and functional, and has control buttons situated near the handle, allowing single-handed change of position. Attachment to and disconnection from the instrument is made possible by a spring-loaded ball-and-socket lock. It is simply controlled by vacuum-lock valves and has the other advantages of being autoclavable and relatively inexpensive. It is the best robotic holder available.

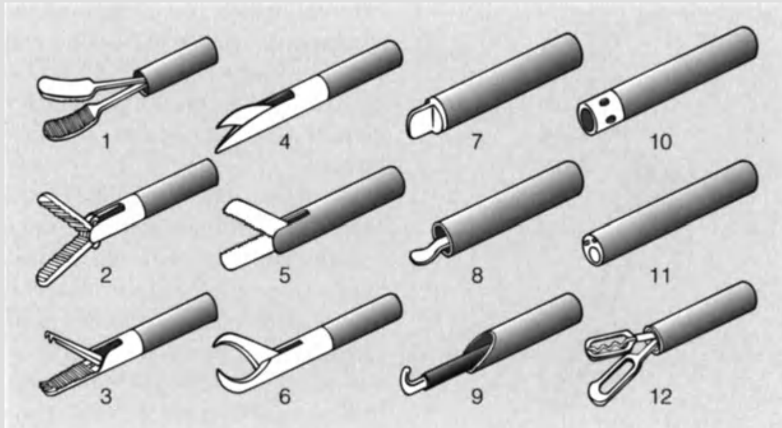
Surgical Requirements for Instrument Holders

Presently Available
- Secure locking in all positions
- Sterilizability
- Unlimited spacial positioning

Future Developments
- Easily controlled locking mechanisms
- Control with a single hand or by foot pedal
- A universal instrument connection system

Fig. 2.17. Robotrac (Aesculap). With control buttons *(S)* in the handpiece, it is possible to control the pneumatic locking of the knuckles *(K)* and steady the instrument with one hand. A remote box *(G)* controls air supply. This fixing device has to be covered by a sterile polyethylene tube





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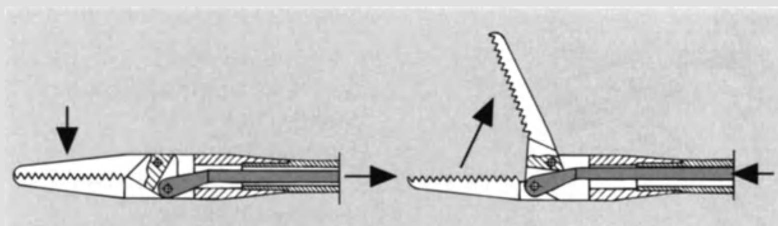

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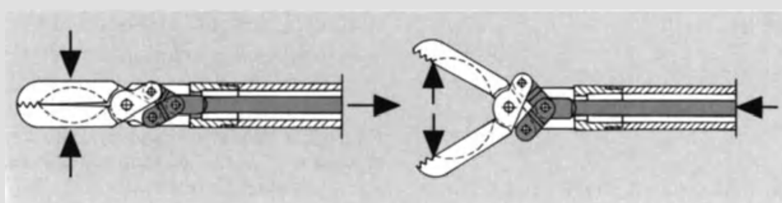


b

Fig. 2.18. Different designs of the instrument tips used in ES (Olympus, Winter & Ibe). *1*, Atraumatic grasping forceps; *2*, grasping forceps; *3*, toothed grasping forceps; *4*, microscissors; *5*, scissors; *6*, hooked scissors; *7*, knife electrode; *8*, spatula electrode with channel; *9*, hook electrode with channel; *10*, coagulating electrode; *11*, bipolar electrode with channel; *12*, bipolar grasping forceps

Fig. 2.19 a, b. Design of twin- or single-action endoscopic forceps (Wolf). **a** Single-action jaws. In this case only two hinges are necessary. **b** Twin-action jaws

Surgical Instruments

The handle and shaft designs of laparoscopic surgical instruments such as forceps, scissors, needle holders, suckers and diathermy instruments were copied from gynaecological instruments and the tips modified for special surgical requirements (Fig. 2.18).

Technology and Assembly of ES Instruments

The materials and construction of ES instruments are governed by four basic functions: grasping, cutting, haemostasis and suction. The construction is hampered by their small diameter and length. Grasping forceps and scissors normally have hinge joints which are single or twin action. Every action of the jaw must be transmitted via two hinge systems. One hinge system is placed in the handle and converts force into an in-and-out movement of a central rod in the shaft of the instrument. At the distal end this rod is connected to one or both jaws with another hinge system. The twin action of the tips of instruments has some practical advantages during surgery, but the force transmitted to the instrument jaws is attenuated by the small dimensions of the jaw connecting rods to the central rod (Fig. 2.19). Furthermore, there are hingeless graspers and coagulation forceps. These graspers em-

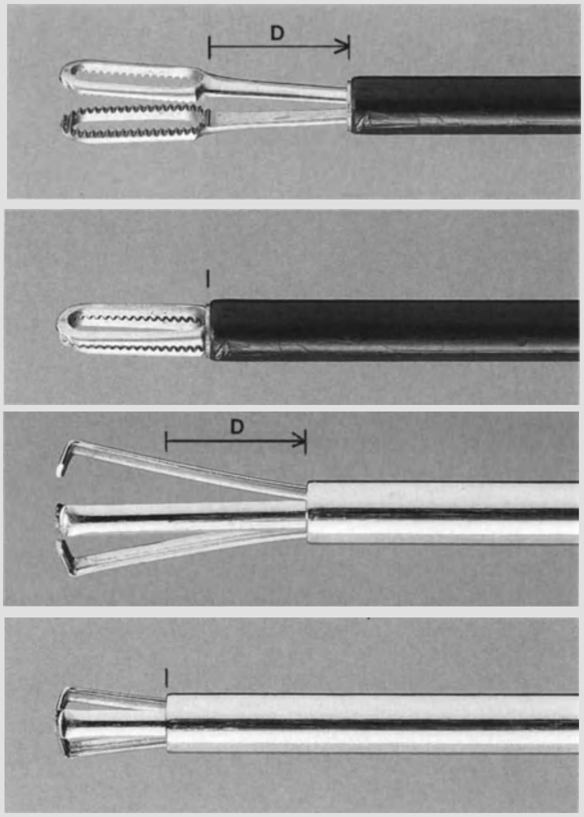


Fig. 2.20. Hingeless grasping and diathermy forceps (Wolf). To allow the object grasped to remain in the jaws as they are closed, the handle and outer part of the shaft must move a distance *(D)* towards the tip

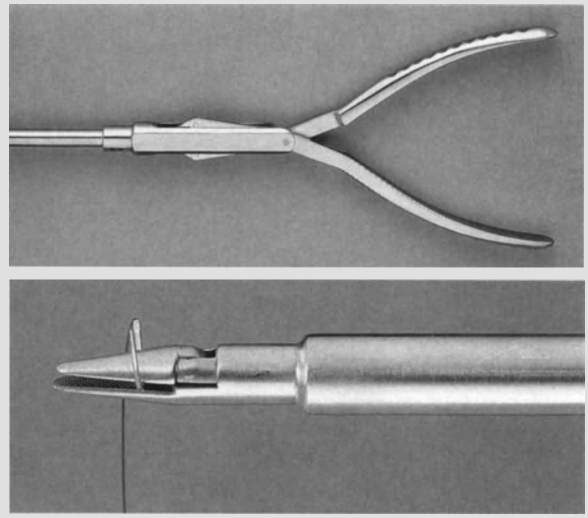


Fig. 2.21. The axially oriented Messroghli handle (Wolf) is easy to manipulate and transmits great forces to the jaws by effeciently using its special hinge design

ploy two to four jaws by simple in-and-out movement of the central rod. The advantage of this construction is that it is strong and more simple to assemble. A disadvantage is that the grasping unit moves as the handle is activated (see "Ergonomics" above) (Fig. 2.20), forcing the surgeon to move the shaft of the instrument to keep the position of the jaws constant.

Long-lasting insulation requires high-quality materials to resist degradation caused by physical and chemical effects. It has to resist mechanical stress and must not react with body fluids to produce toxic substances. In addition, thermal sterilization causes high stresses in both metals and insulation. High-grade stainless steel is required most often. "High-grade" in this sense means the amalgam contains a low iron concentration and a high concentration of chromium, nickel, cobalt, molybdenum and other materials, resulting in better mechanical properties and resistance to corrosion. However, the surface finish of these instruments also affects their corrosion resistance: highly polished surfaces will incur less corrosion compared to matt finishes. The highly polished surface of instrument tips and jaws causes light reflection impairing video camera performance. Matt finishes improve this problem, but are more prone to corrosion.

The instrument handles are similar to those designed for open surgery. Sound ergonomic principles dictate that, to activate the instruments, the ergonomic handle position should not be affected by jaw function and direction. Especially poor in design are the handle finger rings which require insertion of the fingers in order to grip. The axial handle design of Messroghli by Wolf (Fig. 2.21) and the Semm round handles go some way towards solving these problems. Colour identification of instrument functions with these round handles is an advantage; the other benefit is the independent axial rotation of the instrument relative to the surgeon's hand while keeping handle function (Fig. 2.22)

Grasping Forceps

In ES grasping forceps have different functions. In addition to tissue grasping, it is possible to use these instruments for dilatation, atraumatic dissection and, with appropriate insulation and connections, diathermy coagulation. The main difference between traumatic and atraumatic instruments lies in the characteristics of the jaw design, e.g. traumatic jaws have grooves, teeth, etc. (Fig. 2.23)

Fig. 2.22. The various functions of the Semm round handles are colour coded, and manipulation is independent of the tip orientation (Wisap)

Mechanical Cutting Instruments

In ES there are microscalpels which are attachable to a handle and endoscopic scissors. Three types of scissors are available (Fig. 2.23):

- Hook scissors: these allow tissue to be grasped prior to cutting.
- Serrated straight scissors: these are good for successive tissue division.
- Curved scissors: these improve the visibility of the structures within the jaws.

Scissors may also be used for diathermy, but the large non-insulated area and rapid blunting of the cutting surface caused by sparks are substantial drawbacks. Modern diathermy units are able to reduce spark formation by using electronic monitoring of tissue impedance and altering voltages accordingly.

Dissecting Instruments

In ES, high-frequency monopolar diathermy is often used for dissection (see Chap. 4). Hook, knife and spatula electrodes are available. The advantage of these instruments is that tissue is only cut during current activation and small vessels are sealed. Reliable insulation of the entire instrument, apart from the tips, is essential for these instruments. This added insulating layer weakens the instrument. To avoid wide contact areas, the insulation should extend as close as possible to the tip. The integration of suction with these instruments often causes inferior suction function (Fig. 2.23).

Bipolar Diathermy Instruments

Bipolar coagulation forceps work on the same principle as hinge-free graspers. The jaws have to be insulated from each other along the length of the whole instrument. They are useful to control small vessels, e.g. within adhesions. Various instrument designs are available for the application of bipolar diathermy (Fig. 2.23):

- Coagulation forceps with wide loop jaws for coagulation of thick vascular pedicles
- Small straight tips for coagulation of visible vessels
- Bipolar electrode (Fig. 2.18, item 11)

In our opinion, it would be an advantage if water irrigation were used simultaneously during coagulation to limit the temperature between the jaws to a maximum of 100°. This would stop tissue adherence to the jaws and protein carbonization (see Chap. 4). It is also possible to limit the temperature between the jaws using special impedance measurement.

Monopolar Diathermy Instruments

Normally endoscopic suction can be incorporated in these instruments so making them more useful to control bleeding. In addition, insulated grasping forceps are used for haemostasis. An alternative to the use of diathermy instruments is the endocoagulation system developed by Semm (Fig. 2.23) (see Chap. 4).

Needle Holders

Needle holders used for endoscopic surgery are similar in design to those used during conventional surgery: the needle is tightened between the jaws of the instrument either by springs or clamped by a locking mechanism in the handle. The inner calibre of the cannula limits the use of curved needles.

A special needle holder construction by Messroghli with its axial hinged handle mechanism applies sufficient gripping force to use needles of up to 1 mm in diameter (Fig. 2.21). In our opinion, the spring-loaded needle holders are only designed for use with straight needles.

Surgical Requirements for Endoscopic Instruments

Presently available

- Reflection-free instrument surfaces
- Ergonomic handles
- Sealed shafts
- Autoclavibility

Future Developments

- Combination instruments
- Increased dimensions of freedom
- Radiolucency

Combination Instruments

Combining the functions of these long instruments avoids the clumsiness and time taken to exchange them, e. g. a combination of cutting, suction, irrigation and coagulation would improve the ability to avoid bleeding and make its control easier. A sucker with a monopolar diathermy function that transmits scissors within its lumen is an example of this sort of combination instrument (Fig. 2.24). In Tübingen, besides this instrument which is now in routine clinical use, we are continuing to develop other combinations. In 1987 a bipolar forceps was made with water irrigation and a central working channel. A combination bipolar forceps, water irrigation, suction and cutting device (Fig. 2.25) is being developed in cooperation with the Nuclear Research Centre (Karlsruhe).

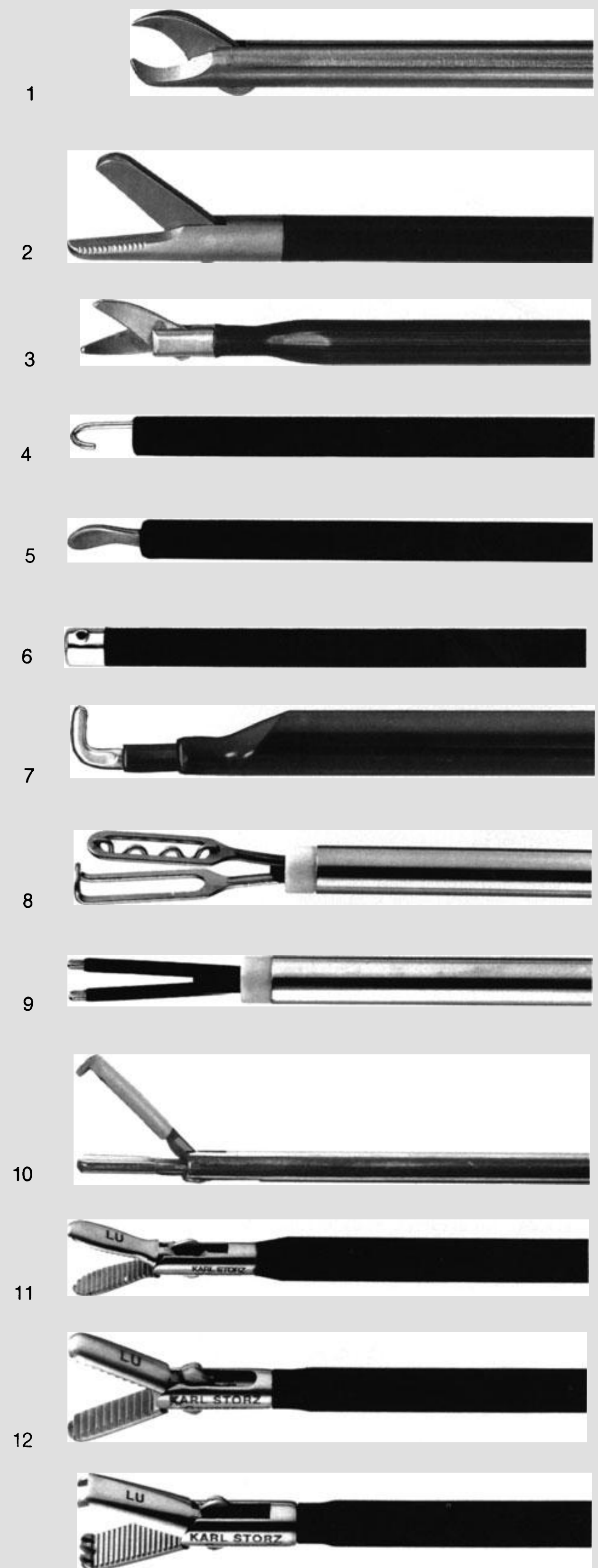
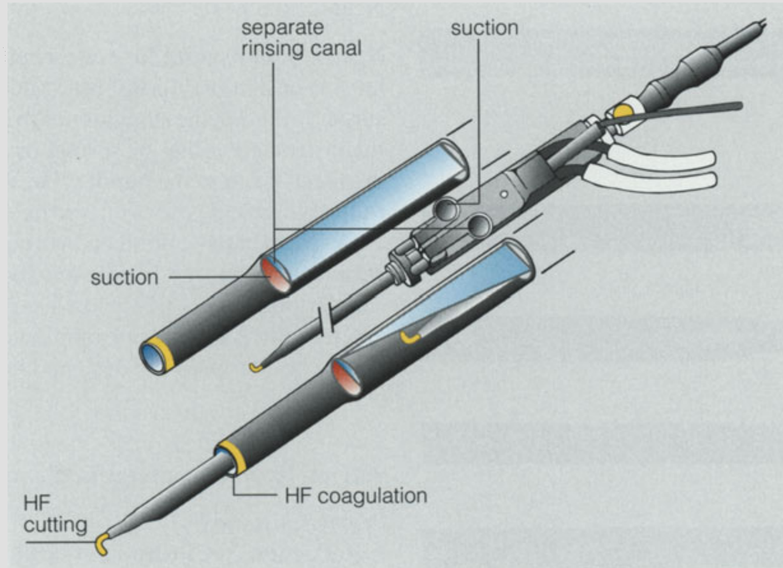


Fig. 2.23. A range of ES instruments: *1,* hook scissors; *2,* straight scissors; *3,* Metzenbaum scissors; *4,* diathermy hook dissector with suction channel; *5,* spatula dissector; *6,* suction cannula allowing coagulation; *7,* standard dissecting hook; *8,* bipolar forceps for wide coagulation; *9,* bipolar forceps for precise coagulation; *10,* Semm endocoagulation forceps; *11–13,* grasping forceps



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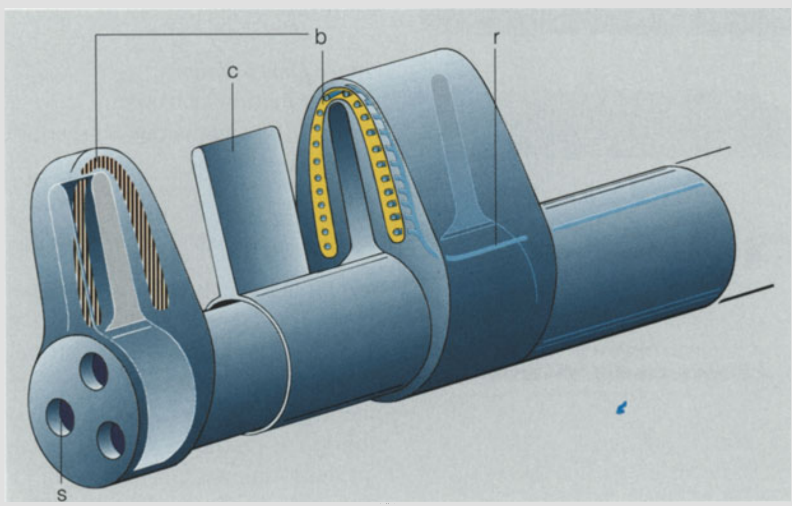

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Fig. 2.24. An enlarged suction channel conveying instruments allows it to function as a simple combination instrument. Partial instrument withdrawal allows prompt use of suction

Fig. 2.25. Bipolar forceps with integrated irrigation, suction and cutting functions. *b* Bipolar coagulation; *c*, cutting blade; *r*, rinsing channels; *s*, suction channel

Clips and Staplers

Clips are made of metal or plastic polydioxanone and approximate tissues or close vessel lumens by their plastic deformability or locking mechanisms. A stapler is a device which applies a series of staples either in a circular or linear fashion.

Development of Surgical Clips and Staplers

The first mechanical closure of wounds was by the Indian physician Susruta. In the six century BC he reported the approximation of skin wounds using the jaws of large ants. Further development of these techniques with the disposable multiple staple delivery devices has seen their widespread introduction into clinical use. Spring clips have for many years been of use in neurosurgery for the control of vessels (e.g.

Fig. 2.26. Clips used in linear and circular staplers are of similar design: as a result of their plastic deformability, they are converted from a "U" to a "B" shape and thereby preserve the capillary circulation

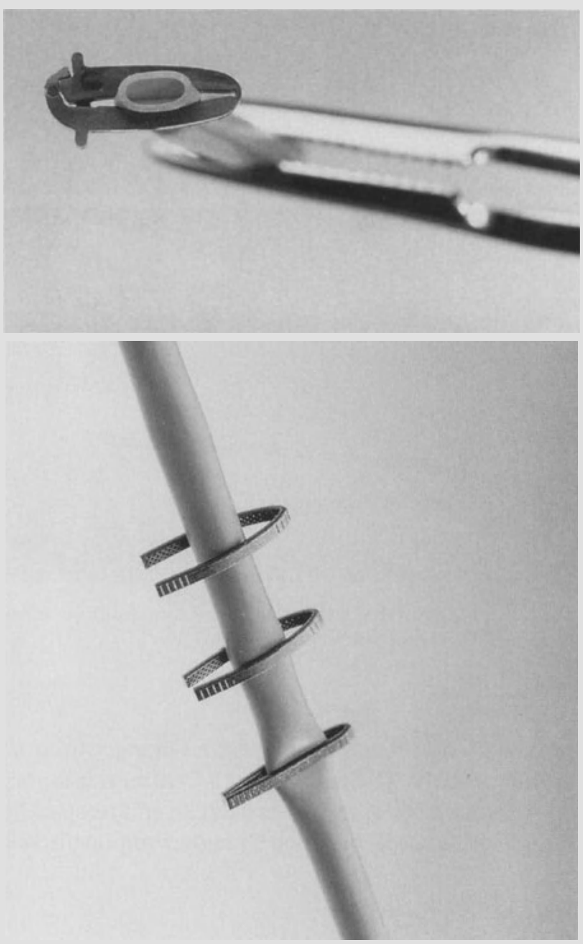
aneurysms). Metal clips which close vessels by plastic deformability induced by an applicator, apply single clips or, in the case of some disposable devices, multiple automatically reloaded clips. The first linear stapler was made by Hütl in 1908 and is the forerunner of all subsequent devices: in one action tissue is approximated, anchored by clips which are closed from a "U" into a "B" shape and then the tissue is divided (Fig. 2.26).

Staple Materials

Ligature clips are made of high-quality stainless steel, titanium or bioabsorbable polymers (Fig. 2.27). The linear stapler clips are normally made of stainless steel as this material has the highest mechanical performance. They are tolerated biologically, i. e. when examined histologically the surrounding tissue shows minimal reaction. However, they induce significant artifacts locally during computed tomographic scaning or magnetic resonance imaging.

The mechanical performance of titanium is two to three times less than that of stainless steel. Titanium is biologically inert, and the surrounding tissue does not react with it. However, titanium ions have been found

a



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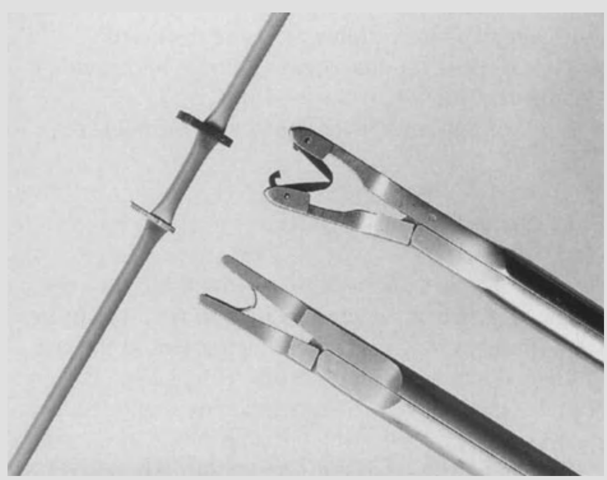


Fig. 2.27 a, b. Surgical clips for vessels: **a** Absolock clip (Ethicon) is made of bioabsorbable polydioxanone. For correct clip function the vessel must be free of surrounding tissue for the lock to close without impediment. **b** Metal clips of either stainless steel or titanium are closed by simple plastic deformation, allowing partial or complete closure around a pedicle

within the lymph node draining areas containing large titanium implants. Titanium has the advantage of inducing only small local image artifacts during computed tomographic scanning or magnetic resonance imaging. Closure of metal clips is achieved by mechanical deformation (Fig. 2.27). The bioabsorbable clips (polyglycolate or polydioxanone) are hydrolysed within tissue and metabolized. They are identifiable radiologically for up to 90 days. In magnetic resonance imaging, high field powers result in images with local artifacts. The main disadvantage of these polymers is their poor mechanical performance (very low plastic deformability). This limits their application for two reasons. The construction of the delicate locking mechanism is difficult and will not function unless the vessel has been completely dissected free from surrounding tissue to prevent tissue obstruction of the locking process (Fig. 2.27).

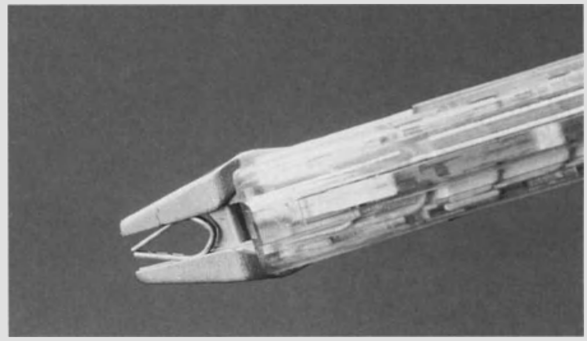
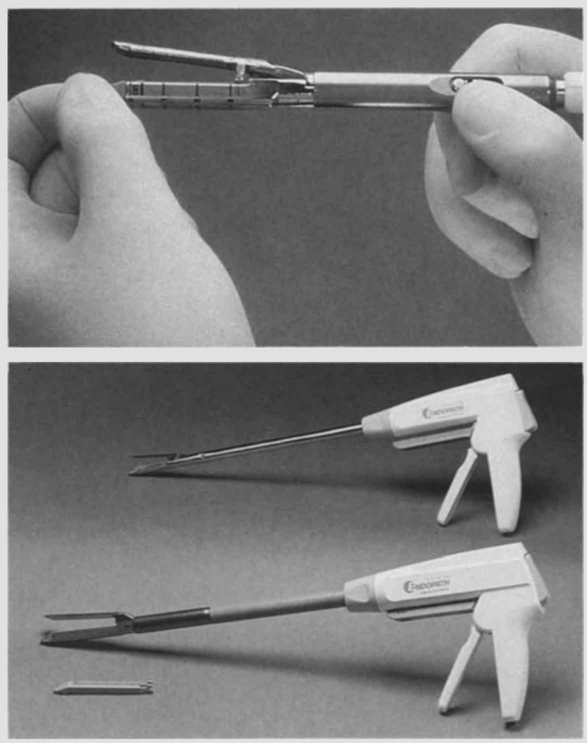


Fig. 2.28. The AutoSuture 10-mm multiple-firing applicator with approximately 20 clips semiautomatically loaded from the shafts



a

b

Fig. 2.29. **a** Endo-GIA stapler, 30 mm (AutoSuture). **b** Endopath ELC, 30 mm and 60 mm (Ethicon)

Surgical Requirements for Clip Systems

Presently Available
- Bioabsorbable materials
- High mechanical performance materials
- Small local artifacts during imaging
- Safe and easy clip closure
- Outer diameter of clips less than 10 mm
- Multiple firing

Future Developments
- Linear stapler adjustable for tissue thickness
- Clips to close luminal organs, hernias and simulate suture ligatures
- Bioabsorbability with better locking mechanisms

Clip Systems Presently Available

The metal ligation clips presently available for endoscopic use are in single-loading or multiple-firing (AutoSuture) configurations which are used through 10-mm diameter access ports (Fig. 2.28). Bioabsorbable clips are at present applied by single-loading forceps.

The linear stapler device (AutoSuture) has two different magazines for variation in tissue thickness. The line of staples is 30 mm long (Fig. 2.29 a). Ethicon is now marketing the Endopath ELC. Stapling lengths are 30 and 60 mm. Two different magazines for different size of tissue are available (Fig. 2.29 b) Clips for closure of hollow viscera were developed in Tübingen (see Chap. 13). Clips for hernia repairs by fascial approximation are being developed in Tübingen in cooperation with the Nuclear Research Centre, Karlsruhe.

Another development has been an endoscopic clip designed to control bleeding by underrunning the vessel.

Future Techniques and Materials in ES

Shaped Memory Metals

Interesting properties of nickel and titanium combinations open up new avenues for instrument design for endoscopic surgery. The special properties are endowed by the metallurgic structure. By nature of their crystalline structure, these nickel/titanium metals are not really alloys in the strict sense of the word, but metal compounds. The titanium and nickel are arranged in spatially oriented atomic configurations in specially designed repetitive patterns. Depending on the metal composition and temperature (approximately 20°–400° C) the structure is in the austenite phase. At lower temperatures, it is in the martensite phase and this can be reversed again by raising the temperature of the metal. Two macroscopic effects result from this transformation: heat-induced changes in shape and superelasticity.

Heat-Induced Changes in Shape

If a nickel/titanium wire is plastically deformed (up to 8%) in its martensite structure, i.e. below its changing temperature, the wire will return to its original shape when heated above its changing temperature, i.e. it will change to its austenite structure. Industrial application of this property is for small oil pressure valves in car engines.

Superelasticity

Depending on the composition of the metal, it is possible to get an effect called "elastic shape memory". Here the martensite/austenite transformation occurs at 400° Celsius. Below this temperature, in the martensite phase, the metals are eight times more elastic than super-spring wire. Above this temperature, these metals have plastic deformability thus allowing them to be shaped, while below 400° plastic deformity is replaced by the elastic properties while a memory of the given shape is still retained.

The superelastic nickel alloys were first used in 1971 by Andreasen and Hillemann in orthodontics. At present they are used in orthopaedics for internal fixation and in vascular surgery for intraluminal stenting. Future applications for endoscopic instruments would be, for example, specially designed graspers and needle holders. These could be inserted through straight cannulae and once inside the peritoneal cavity changed into the curved shape. This could be one solution to increasing the degrees of freedom available to the instrument tip. Doubts remain, however, regarding the lack of resistance of this metal to corrosion. Doping with various metallic compounds alters the metallurgical characteristics of nickel-titanium alloys. New polymers, e.g. polynorbornene, also show a "shape memory" effect during polymerization. Their potential use and biocompatiblity are currently being investigated.

Water-Jet Dissection

In recent years water-jet dissection has been found to be useful during hepatic and neurosurgery. The water jet has been useful for separating tissue while leaving vessels above 0.2 mm intact. These techniques were first developed for industrial applications. Water pressures in the region of thousands of bars, with jet sizes of 0.2–0.5 mm allow cutting of elastic textiles, gums, metals up to 20-mm thickness and stone up to 50-mm thickness. The cutting property of the water jet can be changed by using additives, e.g. polymers or mineral powder. In hepatic surgery the pressure of the water jet is varied from 1.2 to 400 bar. The sizes of the jets vary from 0.03 mm with high pressure up to 0.2 mm with low pressures.

Athanase et al. (1989) described the dependence of the depth of water-jet penetration in cerebral tissue on the calibre of the jet, e.g. for a jet of 0.2-mm calibre at 0.5 bar pressure, the depth of penetration is 1.0 mm. Increasing the pressure to 3.0 bar results in a depth penetration of 3–4.5 mm. In future high-pressure water jets will probably be used in laparoscopic cholecystectomy as will ultrasonic dissection.

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3 Video Imaging and Photodocumentation

M. Paz-Partlow

General Tenets

One of the main thrusts propelling research and development in endoscopy is to devise a more simple and accurate way to perform a given task. An integrant part of almost any new endoscopic procedure, video imaging affords surgeons these ensuing benefits: (a) the surgeon and first assistant can coordinate their approach to accommodate each other; (b) instrumentation needs are anticipated by the scrub technician/nurse since they can follow the surgeon's movements visually; (c) instruments are introduced safely under visual control; (d) anatomical orientations are easily perceived; (e) pathology is clearly defined; (f) simultaneous documentation of the case results in a permanent record which may be reviewed as needed at a later time [1].

Space does not allow for an exhaustive survey of the burgeoning endo-electronic market. Rather, one possible system will be discussed according to our own institution's experience with its attendant limitations and advantages.

No system, regardless of intricacy or expense, will operate at its optimal level without confident, thoroughly trained support staff to implement it. As components in an imaging system are compiled, thought must be given to the relevancy and efficiency of their application within the operating theater. Their integration within the existing routine must be thought out, designating to specific individuals' certain responsibilities. In our case, a special surgical unit composed of endoscopic technicians oversees the maintenance, proper setup, and function of endoscopic instrumentation within the operating rooms, although, owing to the dramatic increase in both number and complexity of cases, cross-training of all operating room staff has become necessary in order to answer surgeons' needs adequately. In-house seminars on instrumentation and basic video documentation techniques have been given on all surgical floors, with periodic updates as new equipment is brought in or surgical techniques are revised. All staff are then proctored through a given number of cases until they can be declared comfortably proficient.

Cogent instructions in advance on how to manipulate the zoom lens, focus, white balance, and how to orient the camera to the telescope are one method of ensuring a well-accomplished procedure. In video-endoscopic surgery, surgeons depend on whoever holds the camera and telescope for their vision. Training the camera operator deserves special attention, since that individual's performance will often influence the outcome.

Each technical advance demands its own location within the theater, obliging us to redesign the physical arrangement for the surgical team's maximal comfort without violating aseptic rules. Correlation of functions among the ancillary appliances (irrigation pump, light source, electrosurgical unit, light source, etc.) will yield floor space more easily navigable by circulating personnel (see Chap. 5)

The judicious placement of monitors around the operating table is predicated by the procedure, surgeon's stance, and preference. Operative pelviscopy requires only one monitor placed at the foot of the table, whereas in laparoscopic cholecystectomy a two-monitor arrangement is preferred. At the patient's right stands the principal video cart, which contains a 48.3-cm high-resolution monitor, 122-mm VHS recorder, 19-mm recorder, and at times a still video printer (Fig. 3.1). It is angled close to the anesthesia cart so as to provide the surgeon, who stands on the patient's left, with a comfortable direct view of the screen. In a space-saving effort, the 33-cm high-resolution monitor, which faces the first assistant, is housed atop an insufflator stand that also houses the insufflator, CO_2 cylinders, and a small irrigation pump. It is posted at the head of the table, on the patient's left (Fig. 3.2). Along the back wall, a third ceiling-mounted monitor allows the support staff to observe. All three monitors are looped sequentially with termination on at the last one.

The expense of a documentation system is only justified if its implementation is meticulous, consistent, and well executed in the most expedient fashion. After

Fig. 3.1. Primary video cart shows variety of photodocumentary equipment utilized in the operating theater

multiple evaluations, we have selected equipment that will serve dependably under a variety of users. Hands-on in-service training allows staff to become familiar with the various functions outside the sometimes tense atmosphere of the operating theater, bolstering their confidence and reducing recalcitrant attitudes towards new technology. By cross-training operating room personnel we try to ensure adequate coverage throughout the schedule. The following is a concise listing of each item, its purpose, and basic specifications.

Telescope

This is an obvious truism which is often ignored: be certain that the telescope is undamaged before starting the operation. Chips at the proximal or distal end can distort the image. Broken fibers can reduce the light output significantly. Warm the telescope to body temperature before insertion, wiping the eyepiece dry to prevent moisture condensation in the space between it and the camera lens. These elementary precautions can cut down on false starts and unnecessary frustration.

Light Source

While illumination demands in arthroscopy or urology can be met by smaller light sources, the abdomen necessitates the most powerful light available. Several firms offer high-intensity units based on the same 300-W xenon lamp, but the Storz 610 Automatic Xenon is still the brightest, most dependable unit for use with rigid telescopes. This unit offers automatic light control for video while also serving as a flash generator for still photography (35-mm slides) [2].

Monitors

Although there exists an immense variety in TV monitors, including NEC, Zenith, and Toshiba, most endoscopic manufacturers have standardized on Sony, offering one or another of their models as part of their packages. The minute details which the surgeon must perceive in complex endoscopic surgery make it imperative that the monitor image quality possess superior color, resolution, and clarity. Presently, we place a 48.3-cm Sony PVM-1943MD opposite the primary surgeon and the 33-cm model (PVM-1343MD) vis-à-vis the first assistant. These studio monitors yield approximately 700 lines of horizontal resolution, capably accommodating even the sharpest camera. In comparison, the ceiling- mounted monitor is a standard PVM-1910 with only 350 lines of horizontal resolution. A third model, the Sony PVM-2030, offers 580 lines of horizontal resolution, good chroma, more contrast, and a price somewhere between the two models mentioned above.

Cameras

Owing to our high-volume usage and profound interest in endoscopic research, our institution is fortunate in being able to evaluate new products while still at the prototype stage, which gives us an edge at acquisition

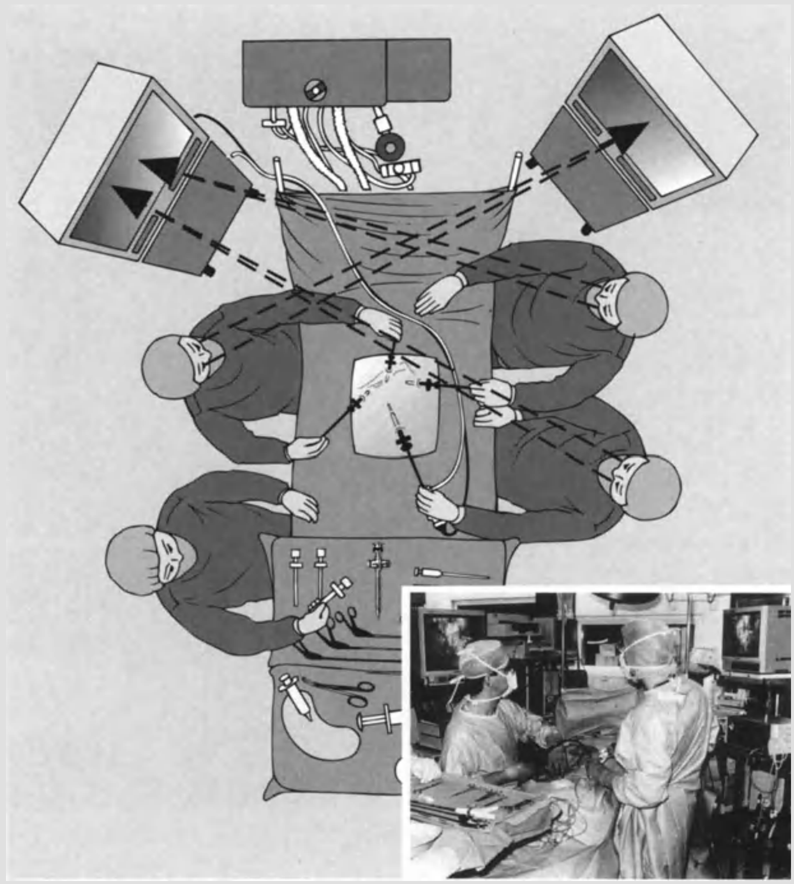
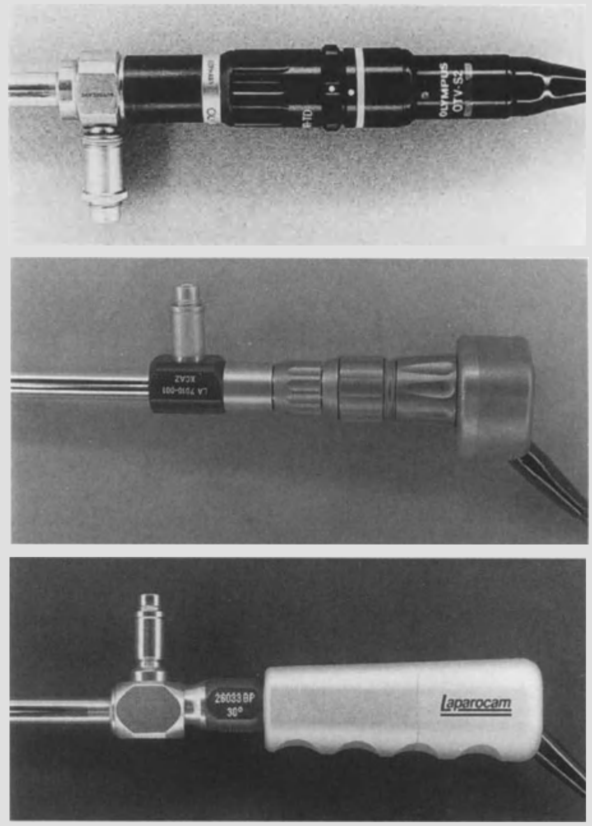


Fig. 3.2. A two-monitor approach to laparoscopic cholecystectomy

time. However, even we cannot possibly keep up with all the transmutations in endoscopic microchip cameras. Today's solid-state cameras are designed around chips which typically hold 150000–300000 pixels (smallest unit of picture elements in an image; outer diameter, 17×13 μm). The silicon charge-coupled device (CCD) was recognized as suitable for video applications several decades ago [3]. These systems must be compatible with standard TV formats (525 or 625 lines), so the scanning rates run 200000–300000 pixels per frame at a 30-Hz frame rate, producing an output rate of about 10 megapixels per second. The number of pixels on a chip determines the resolution, each one procreated by a receptor in a densely packed grid of photocell receptors. A well-fabricated, lightweight CCD camera, sterilizable both by ethylene oxide gas and gluteraldehyde, is indispensable for endoscopic surgery, for tube cameras were too heavy, too clumsy, and not nearly light-sensitive enough for most applications.

Our current model returns to us the color rendition we had had to sacrifice for light sensitivity with the 1/2″ (13-mm) chip camera. The video sensor in the Storz 9050B is a Sony 2/3″ (17-mm) interline transfer CCD which makes it shutterable. Automatic exposure is microprocessor controlled, ranging from 1/60–1/10000. Its scanning system is a 2:1 interlace, with internal synchronization and a signal to-noise ratio of 47 dB or greater. The horizontal resolution is more than 450 lines with minimal illumination requirements of 7 lux at f1.4. It also features automatic white balance with a range of 2200K–9000K. The head measures 34×86 mm and weighs 127 g with a 3-m cable attached. It is designed with a built-in zoom lens extending from 25 to 40 mm (Fig. 3.3). We have purchased several of these cameras for use in laparoscopic cholecystectomies while continuing to employ older models in other areas until their replacement can be fiscally justified by either depreciation or increased case load.

Fig. 3.3. A new 2/3″ (17-mm) CCD camera features automatic white balance and iris



a

b

c

Fig. 3.4. a Olympus 1/2″ (13-mm) CCD camera coupled glass-to-glass to 0° optic. **b** Baxter-V. Mueller version of arrangement described above employing a 2/3″ (17-mm) chip as camera sensor. **c** Storz Lapcam consolidates a 2/3″ (17-mm) CCD sensor and optics ocular within a handgrip, eliminating variable focus

Other vendors offer similar cameras, although most are based on 1/2″ (13-mm) CCD chips.

Sometimes early potential will not come to fruition. After extensive evaluation, we are abandoning use of the HR-3000 three-CCD camera until its technical difficulties can be surmounted. The model has shown a consistent propensity to overheating, which can cause loss of image and/or misalignment of chips resulting in image distortion through loss of registration. It may be some time before this camera is ready for routine field service. Stryker Endoscopy is marketing a three-chip camera based on three 1/2″ (13-mm) CCD image sensors with interchangeable heads, but we have no clinical experience with it.

Even as the 9050 B was introduced, further innovations in camera design were coming to the fore. Under clinical trial, we have inspected several systems which eliminate the traditional coupler and eyepiece connection, joining lens to ocular "glass to glass." This can eliminate misting in the interface between scope and lens and tends to give a bright, crisp image. The lenses used in these cameras are of a specific focal length, either 30 mm or 38 mm.

Olympus has a 0° 10-mm laparoscope (steam autoclavable) coupled with a minute camera based on a Panasonic 1/2″ (13-mm) chip (Fig. 3.4 a). Baxter has a similar arrangement, although theirs is a 2/3″ (17-mm) CCD camera (Fig. 3.4 b). The Storz Lapcam encases camera head and telescope ocular in a sealed, moisture-proof handgrip, obviating the need to focus (Fig. 3.4 c). We have experienced good results with this model. A drawback to these designs is the loss of zoom capability, since at times the highest magnification is desired, as when incising the cystic duct prior to cholangiography. Fujinon has exhibited a video-laparoscope, but, although test tapes looked adequate, we have no personal experience with it. The acquisition of any video system requires prospective buyers to experience at first hand an assortment of brands and types in order to ascertain which will best fulfill their needs.

Documentation

35-mm Photography

Electronic photography may be defined as still images created, transmitted, or manipulated electronically. It is generally agreed that in order for electronic photography to compete viably with film, resolution of at least 2000 lines (scan lines) would be needed to achieve any semblance of the definition of film for the purpose of graphic reproduction. Here are some rough figures which compare the resolution of film and electronic imaging chips: AP wire photo, 8×10 print: approximately 2.5 million pixels; Kodak megapixel sensor: 1.4 million pixels; still-video sensors: 200000 to 380000 pixels.

Presently 35 mm offers images having more than 15 times the information most still video systems produce. While no one would dispute the superior quality of film documentation over that of video, the difficulties inherent in obtaining the former point to its decreasing utilization. We devised a system in the 1980s whereby an articulated arm containing a 90/10 beam splitter was attached to the telescope's eyepiece and a 35-mm camera was connected to the arm's proximal end. Thus, the surgeon was able to continue the procedure while the assistant photographed the desired sequences. This method gave satisfactory results in some areas such as urology and laryngology, but laparoscopy has always presented additional challenges because of light loss through the articulated arm.

For lecturing and publication, the best 35-mm slides are achieved by coupling the 35-mm camera by means of a special endoscopic lens directly to the scope's eyepiece. This is not only awkward for the operator, given the camera's weight, but deprives the rest of the team of a visual image while shooting proceeds. It also brings us the significant problem of maintaining sterility. As one will often want progressing views of the procedure, the logistics for successful 35-mm photography are somewhat involved. Multiple telescopes need to be employed, as at least two must be soaking at all times to replace the one the surgeon is using and which has just been made unsterile by its contact with the camera. The camera itself may be bagged, but this makes the controls difficult to handle. The surgeon must double-glove continuously, stripping one pair off and donning another after each shot. Additionally, the strobe's sync cord presents one more obstacle in maintaining sterility.

We employ the Storz Xenon 610's automatic flash capabilities, thus cutting out the need for an additional flash source as it provides continuous light for video as well. In order for the flash to perform at full capacity, the unit's light intensity must be turned to maximum. It may be operated with both manual and automatic settings. The camera must be adjusted accordingly and its shutter speed set at 1/30 second. Flash duration ranges from 1 to 30 ms, considerably longer than conventional electronic flashes. Ektachrome 400 ASA is our usual film, although negative film of the same speed may also be used. Processing normally takes 24 h, although a nearby lab offers 2- to 3-h processing at greater expense.

If this process is deemed too complex, slides may shot from video tape using the Polaroid Freezeframe video recorder, which has available both Polaroid 4×5 hard copy and 35-mm film backs. The unit has a "frame grabber" board which allows one to capture a field which is then photographed by the unit by means of a high-resolution cathode-ray tube within it. Ektachrome, either 100 or 64 ASA, gives the best results. A hard copy from video tape may be made with this unit as well, but superior results will achieved with Sony's Mavigraph UP-5000.

Even with the modest resolution that most types of electronic photography offer, the benefits of electronic imaging still make it appealing. The power of digital imaging is not so much its resolution – film still wins that battle – but rather its ease of manipulation, of transmission, and of data extraction. These are the aspects which make us willing to accept lower-resolution images.

Video Format

The higher resolution of the newer cameras confronts us with the shortcomings of our video-recording equipment. As our video library is heavily relied upon for teaching and lecture tapes, interesting procedures are recorded on 19-mm U-matic format. The cut-only editing suite with which we prepare lectures and workprints is also 19 mm. While our camera can deliver over 450-line resolution, these U-matic recorders, being 5 years old, can only record up to 270 lines. To continue as we are means we are not formulating the best-possible recordings; to upgrade the system involves substantial capital expense in a period of economic retrenchment and the addition of yet one more tape format.

Any of the three formats, S-VHS, ED-Beta and Hiband 8 mm (Hi8) will record at a horizontal resolution of 400 lines. All require new hardware, but with Hi8 it may be possible for us to upgrade gradually. In the Hi8 format, the luminance FM carrier has been increased and the frequency deviation expanded. This gives better color reproduction and picture quality, especially since a different metal particle tape has been developed for it.

An EVO-9800 Hi8 recorder could be used to record oringinal tape during an operation. With a 33-pin editing interface it could be connected to our existing RM-440 editing controller, thus acting as source player. This would save a generation in conversion from 8 mm to 19 mm, and our edited master would be a 19-mm tape which can be shown almost anywhere.

Eventually we would move up to an RM-450 editing controller and an SP U-matic VO-9850 editor recorder which would give us edited masters from excellent originals with a resolution of 320 lines and outstanding integrity for duplication, one aspect in which U-matic is still the leader. This would be one possible solution to our quandary.

Video Tape Recorders

This is another area where one is faced with almost bewildering variety. It is not possible to predict electronic developments; anything we buy today will be obsolete a year, sometimes only months from now. But it must be remembered that obsolescence is not equivalent to uselessness. Obsolescence is only an issue when repair parts are no longer manufactured, and the particular unit no longer fits one's needs. With this most prevalent form of documentation, it is feasible to record specific segments or an entire procedure at will. Video tapes can be revised through editing and used as individual case presentations and/or as part of more polished instructional media. We provide multiple video carts on each surgical floor, each equipped with two video tape recorders which may be used separately or simultaneously (Fig. 3.5). When a recording is meant for the teaching library, the Sony VO-5800 19-mm U-matic recorder is utilized. For routine applications, the Panasonic AG-6300 VHS recorder is more than adequate. Since many of our attending surgeons have VHS recorders in their offices, they regularly record VHS tapes for their files and for patient education, some even giving the patient a copy of his/her procedure. It must be remembered that four 2-h VHS cassettes can be obtained at the same expense as a 60-h min U-matic cassette and can be more easily stored. Real-time counters and variable visual search are useful features on machines on our carts along with momentary contact footswitches to enable the pause mode. One should reflect on the desired end use for a video tape record before purchasing a format, since a serious commitment in finances, space, and personnel is required for a viable tape library.

Disk Recorders

Another option for saving endoscopic information is to store multiple images on optical or floppy disks. Sony and Panasonic market laser disk systems which record stills onto a laser disk with 580-line horizontal resolution at a considerable expense. More reasonably priced are the Canon and Sony floppy disk recorders with which up to 50 fields or 25 video frames (1 frame=2 fields) can be stored on a $2^1/_2$″ two-sided floppy disk. Disk resolution averages 350-400 lines, which can result in superb pictures depending on the printer used. Owing to their diminutive size, disks are easily stored, and, with an adequate catalog, earlier images are simple to recover. Following outpatient procedures such as arthroscopy or diagnostic gynecological laparoscopy, our surgeons will review the frames taken during the operation and select the most fitting shots which are then printed by a still video printer. These prints may then be shown to colleagues for consultation, shown to the patient in explaining the findings, and/or inserted in the chart to become part of the patient's official record [4].

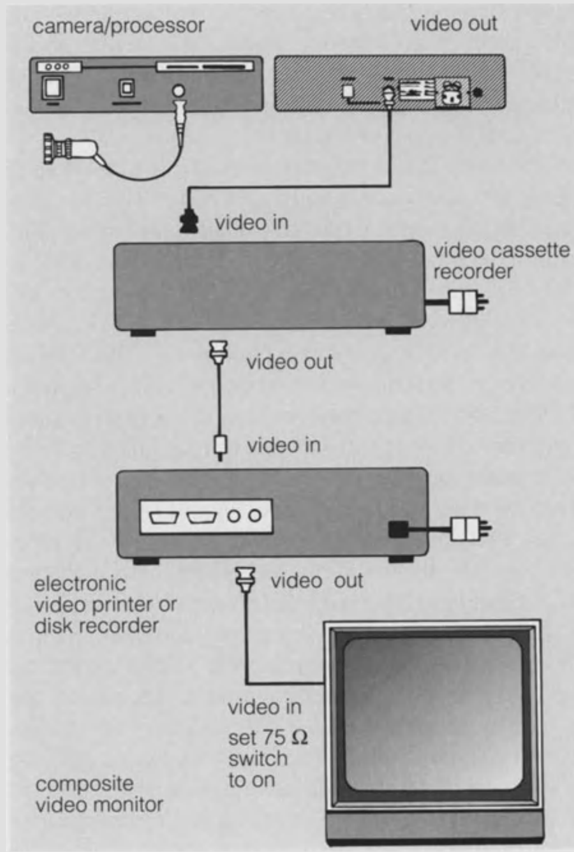


Fig. 3.5. Schematic diagram showing connections in video system

a

b

Fig. 3.6. **a** Sony Mavigraph 5000 still video printer. **b** Close-up of control panel

Still Video Printer

At the writing of this essay, during Photokina, one of the largest annual photography shows, Chinon, Fuji, Konica, Olympus, Ricoh, and Toshiba all announced the imminent introduction of digital still video systems. This incident reinforces the author's observations on the inability to keep up financially and practically with new technological advances. Of the printers already on the market, we would continue to recommend the Sony Mavigraph UP-5000 over those of Hitachi, Kodak, Polaroid, and Canon, their lower prices notwithstanding. It is dye-transfer thermal printer with a one-page memory which can be configured to print full size (166.7 mm×121 mm; 6×9″), or can be subdivided into either four or nine separate spaces on the page (Fig. 3.6).

With an optional additional one-page memory board which may be inserted, the Mavigraph can record a full page of information, switch pages, and continue to record new information on the second page while printing the first simultaneously. Each print takes approximately 60 s and costs about US$ 1.25. Recently, a more economical model, the UP-3000, has been introduced.

ES ushers in an era of surgical procedures which were hardly conceivable not so long ago. To fulfill the needs of surgeons attempting these brave new approaches, we must assemble a complex melange of electronic and endoscopic instrumentation worthy of their efforts. On the part of medical institutions, this entails firm pledges of finances and manpower which may strain existing resources. Collaboration between specialties, although often difficult, should be sought, since multiple users can help to justify elaborate video systems.

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4 Ancillary Technology: Electrocautery, Thermocoagulation and Laser

H.-D. Reidenbach and G. Buess

With a Section by J. Keckstein

Introduction

During the past decade endoscopic techniques have been increasingly used in surgical treatment with considerable benefit to patient care. In carrying out surgical procedures, the different methods of incision, dissection and coagulation are of special importance, and a full understanding of the principles governing their safe usage by the surgeon is essential. The endoscopic surgical approach has led to modifications and new developments of the operative ancillary technology. In addition to familiarization with the actual instruments, knowledge concerning the interaction of the applied technology with biological tissue is of decisive significance in ensuring a consistently favourable outcome after surgical intervention.

Application of Therapeutic Heat

The use of operative and therapeutic heat with the object of disintegration, destruction or coagulation of biological tissue is almost as old as medical science itself when one considers that Hippocrates regarded fire as the *ultima ratio.* The effect of thermal energy on biological tissue depends on the temperature used. Table 4.1 gives an overview of the tissue reactions which are associated with different thermal thresholds or ranges.

Figure 4.1 shows the important methods for the production of operative-therapeutic heat. At first sight, the method by which the heating of tissue is produced may appear inconsequential. But looked at more closely, especially in relation to their dynamic usage, the various options for the production of operative-therapeutic heat differ in efficiency, rate of change of temperature, attainable maximal temperature, degree of extension in area or volume, dosage, transfer onto the site of treatment and handling.

A classification into, for example, coagulative and incisional methods is meaningless since these different effects may be obtained using the same physical system, irrespective of the applicators or probes used. In this regard, the shape and nature of the probe tip which is in close contact with the tissue or the applicator tip directed onto the target tissue, though often ignored, is frequently the key factor in determining the intended effect.

From a macroscopical point of view, thermally induced coagulation results in a well-demarcated zone in which the proteins are coagulated, i.e. an irreversible change from the colloidal state of tissue into the insoluble gel.

Various mechanisms may participate in haemostasis. In addition to the contraction of the vessel walls, shrinkage of the surrounding tissue and the formation of an endoluminal thrombus are involved.

If heat energy is delivered rapidly within a relatively small volume, such that no appreciable diffusion of heat through cell liquids and membranes occurs, intra-

Table 4.1. Thermal effects in biological tissue

Temperature range (°C)	Thermal effect
37–42	Heating without irreversible damage
>42	Enzymes and other sensitive metabolic molecular components become altered
43–45	Conformational change; hyperthermic retraction and shrinkage; cell death
>50	Inactivation of enzyme activity
45–60	Hyperaemia; oedema with loosening of membranes; swelling
>60	Protein denaturation; coagulation and necrosis; white-grey discolouration of the tissue; shrinkage
>80	Collagen denaturation; membrane permeabilization
>100	Boiling of water in the cells and in the intercellular matrix (more than 1000-fold increase of volume); cell explosion and tissue cavitation
100–300	Dehydration; water evaporation; carbonization
>150	Carbonization
300–400	Smoke generation from carbonization; blackening of tissue
>300	Vaporization of the solid tissue matrix
>500	Burning of tissue; pyrolysis in presence of atmospheric oxygen (evaporization)

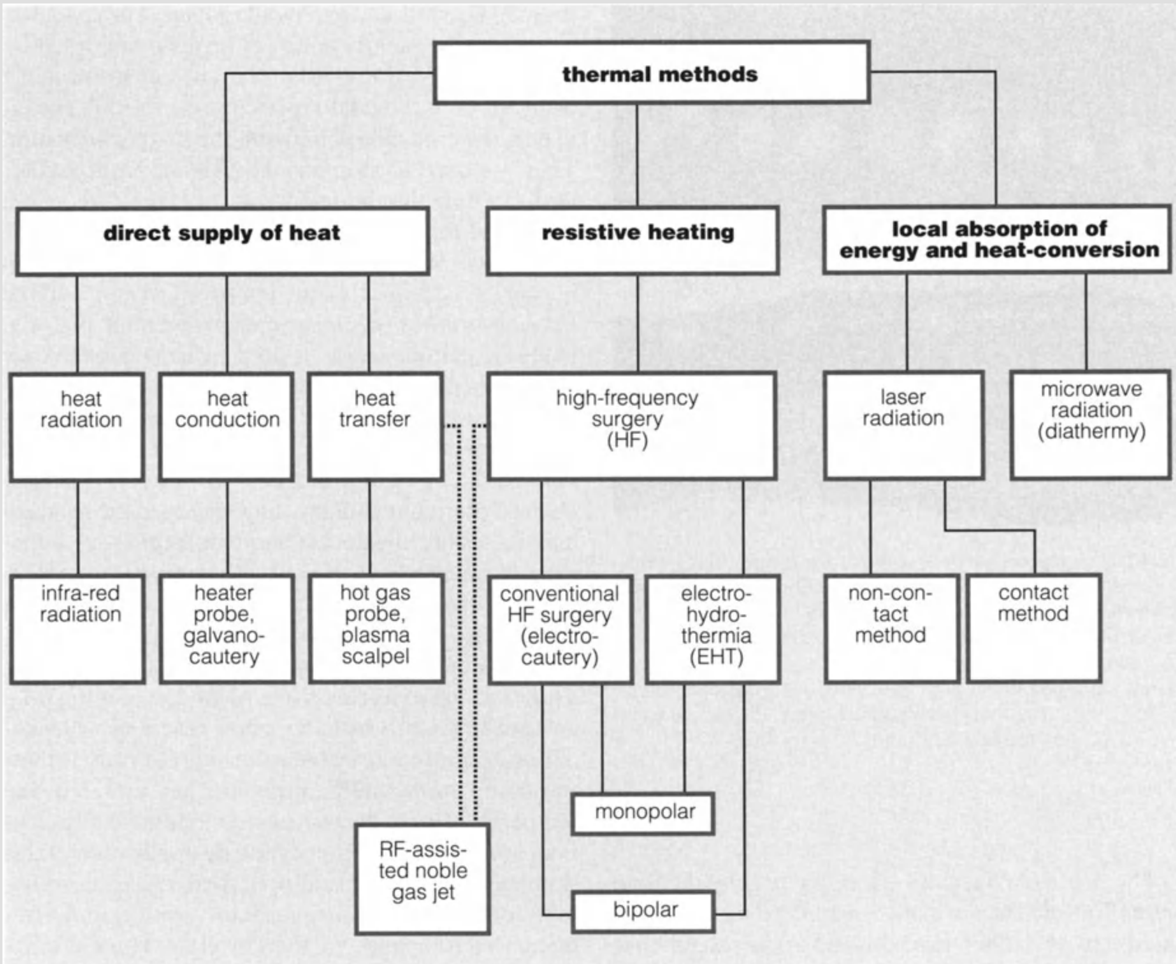

Fig. 4.1. Methods for the production of operative-therapeutic heat

cellular water boils and the increasing steam pressure causes an explosion-like disruption of the tissue, whereby the sectioned surfaces become coagulated to a greater or lesser extent.

Thermal Methods

Thermocoagulation

By direct supply of heat, radiative, conductive or convective (Fig. 4.1), not only coagulative but also destructive interactions may be obtained. For example, incoherent *infrared or heat radiation* with a maximal emission in the spectral range of 900–1000 nm can be produced by means of a 200-W tungsten-halogen filament. The infrared radiation is guided through a large light guide to a specially shaped probe which is pressed onto the tissue surface. The probe consists of a transparent and highly heat-conducting sapphire crystal with a high melting point. When the infrared coagulator is pressed onto a flat tissue surface, e. g. cut bleeding parenchyma of an organ, further blood loss is suppressed mechanically and the superficial vessels are compressed by the probe, while the incident infrared radiation produces a thermally induced vessel occlusion. Since wavelength-selective absorption of the applied infrared radiation is largely absent in tissue and the penetration depth of this wavelength range is comparatively large, the thermally induced coagulation zone extends to some millimeters in depth (no. 6 in Fig. 4.2).

Fig. 4.2. Thermal coagulation (comparison of the effect by various modalities on liver tissue). *1*, Coagulation by soldering iron, no thermostat; *2*, endocoagulation at 100°C; *3*, conventional RF coagulation with a 4-mm ball electrode; *4*, EHT coagulation with a 2.3-mm probe; *5*, EHT coagulation with a 2.3-mm probe (probe moved across the surface during current flow); *6*, infrared coagulation; *7*, argon-ion laser coagulation; *8*, Nd: YAG laser coagulation; *9*, CO_2 laser coagulation

The depth of coagulation is influenced by the time of application. Because of the sapphire tip or fluorinated caps, the adherence of the tip to the coagulum is largely avoided. Thus the probe can be removed mechanically without damage or dislodgement of the clot. The application of infrared coagulation with flexible endoscopes is limited by physical constraints. On the other hand, it can be used inside large rigid endoscopes.

Direct heat may also be applied to the tissue by the *heater probe*, the *endocoagulator* and *galvanocautery*. In this instance, a metallic probe is heated directly or indirectly by means of an electric current using the same principle as a soldering iron.

The miniaturized heater probe is coated with polytetrafluorethylene (Teflon) and is used successfully in the endoscopic control of gastrointestinal bleeding.

In the endocoagulator, a resistor in the interior of the probe is heated by a direct current and warms the electrically isolated exterior of the probe indirectly by conduction. In this way, current flow through the biological tissues is avoided. The temperature of the probe is controlled by an integrated sensor and can be adjusted to induce protein coagulation at about 100°C (no. 2 in Fig. 4.2). The slow heating results in minimal thermal necrosis and avoids adherence. The coagulated area subsequently becomes invaded and lysed by histiocytes and fibroblasts. The current instruments using the endocoagulator principle are the point coagulator, the crocodile clamp and the myomenucleator. They are used to stop bleeding arising from smaller vessels within the abdomen.

One of the oldest auxiliary surgical means is *thermocautery*. When first introduced as the Paquelin burner, it consisted of an improved version of the glowing iron. In this instrument, a metallic pin, e.g. made of platinum, was heated to incandescence by means of a petrol-air mixture. The successor to this device is the low-frequency cautery or galvanocautery. Using power ranging from 20 to 60 W at relatively low voltages (2–6 V) and currents (10–20 A), the Deschamps platinum-iridium sling can be used to grasp and thermally divide extensive membranous adhesions in fractions of a second with concomitant coagulation of the divided surfaces. However, the glowing cautery tips cause adherence to carbonized tissue owing to the high temperatures reached (600°–1000°C). Thus burning of tissues is inevitable (no. 1 in Fig. 4.2), and healing occurs by hyperaemic reactions with exudation of fluid comparable to healing of burns. If thermostatic control mechanisms are incorporated, the temperature may be preselected automatically. This improvement will enhance the safe application of this simple instrument. In addition, there exists the possibility of combining galvanocautery with a radio-frequency (RF) apparatus, thereby creating an alternative RF electrode.

Another method of direct heat supply is provided by *hot gas probes* and the *plasma scalpel*. In the hot gas probe, a nitrogen-inert gas stream is heated to about 1500°C in a miniature probe which is used for non-contact coagulation. However, experimental investigations have shown that the resulting coagulum is porous and therefore does not provide safe haemostasis.

Recently the argon-plasma jet (argon beamer) has been developed. This delivers a cone of argon which surrounds high-frequency (HF) arcs, produced by standard HF generators, and is used to spray coagulate bleeding vessels and capillaries. The argon beamer/HF spray coagulation system is one of the most effective and safe methods of haemostasis in both open surgery and ES.

The plasma scalpel, on the other hand, has been available for years. A gas such as argon or helium is heated up to about 3000°C in an electric arc and is then concentrated to a cutting jet of less than 1 mm in diameter at a power of approximately 50 W.

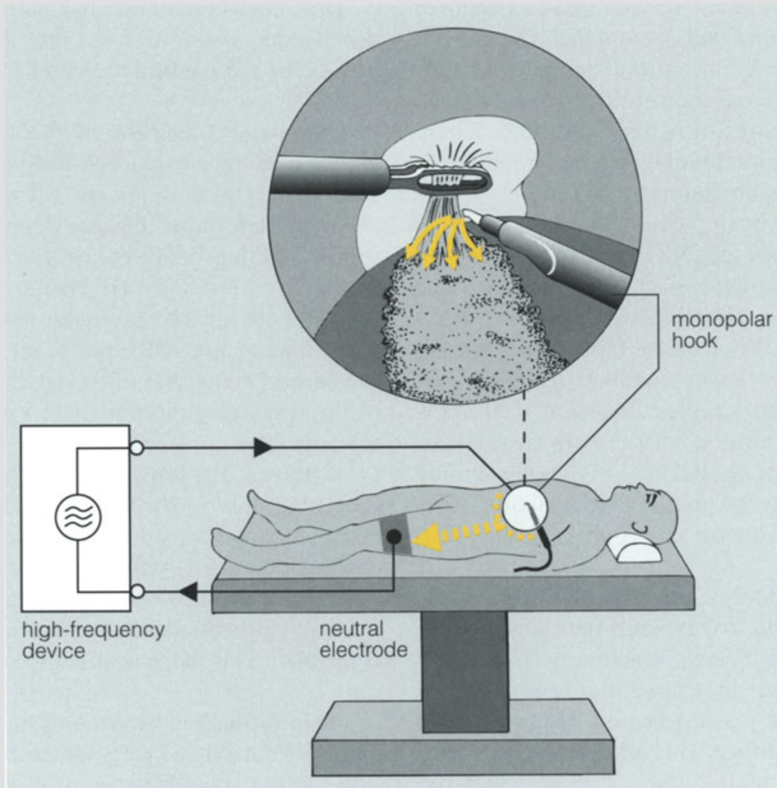

Fig. 4.3. Principle of monopolar HF surgery in gallbladder dissection (*yellow*)

Electrocautery

The term "electrocautery" or in short "cautery" refers to an instrument, used originally for burning. It consisted of apparatus which utilized a low voltage to heat the instrumental tip. The tissue was destroyed by contact with the hot cautery electrode, i. e. through coagulation necrosis. As penetration was by heat conduction, the depth of penetration was difficult to control and required considerable experimental assessments.

Subsequently the term "electrocautery" was loosely applied to other instrumentation such as HF or RF generators. Although strictly incorrect, this terminology is used in this chapter because of its well-established usage in English-speaking countries. Another term "diathermy" which derives from the physical heating achieved by these techniques, is often used by English- and German-speaking surgeons. Sometimes the term is qualified as "HF diathermy" although the appropriate qualification of this terminology is "surgical diathermy" since this accurately reflects a localized tissue effect when the method of HF surgery is used.

HF surgery is the application of HF currents in the frequency range of 300 kHz up to several MHz to perform coagulation, desiccation, fulguration, spray coagulation and ablation of tissue.

From an electrophysiological standpoint, biological tissue consists of series of electrolytical conductors, where the different intra- and intercellular salt solutions are separated by biological membranes. A direct or low-frequency alternating current, e. g. mains current, would alter the ionicity of the cells by neurosensoric reactions if applied in the vicinity of nerves, i. e. it induces a faradic stimulation. On the other hand, if one uses a current with a sinusoidal-periodic waveform at a frequency high enough that the duration of one halfwave is shorter than the minimal stimulation time, any rhythmic excitation will be excluded, and heat alone is developed in the target of tissue. That is the reason why HF apparatus is designed to produce currents at frequencies from about 400 to 700 kHz.

In order that a current is able to flow through tissue, a closed electrical loop is necessary. In the case of the *monopolar* technique, this consists of HF apparatus and an electrical wire or cable leading to a working or active electrode at one end, from which the current "flows into" the tissue. The current "leaves" the body at the same site via a large neutral electrode and "flows back" to the generator through a return line. Figure 4.3 depicts this situation in relation to monopolar HF coagulation during gallbladder dissection.

In a HF current circuit, heating occurs not only in areas with small cross-sections, but also at sites with low electrical conductivity. Since the contact surface provided by the active electrode with the tissue forms only a relatively small area and as biological tissue exhibits a significantly lower conductivity compared with the metallic electrode, the conversion of HF energy into heat is concentrated onto a relatively small local volume of interaction. Because of the outstanding thermal conductivity of modern coagulation electrodes, they remain almost cold during the application.

An analytical model of the situation in homogeneous tissue is used to explain the temperature changes. Immediately below the active electrode, current density decreases in a quadratic fashion as the cross-section increases as a function of the distance from the electrode surface. This results in a tissue temperature profile, the temperature decreasing with the fourth power as the distance from the probe increases. Thus the tissue temperature is directly proportional to the square of the current density.

In the model, the resulting coagulation depth, i.e. the penetration depth in which the temperature threshold for coagulation of 63°C is reached, amounts to only about 15% of the electrode contact surface diameter. It has been shown experimentally that these conditions apply only when the coagulation time is relatively short, i.e. for example, at current duration times shorter than 1 s and when high power is simultaneously applied.

The heat produced by HF surgery is endothermic as distinct from the external heat supplied by cautery. The conduction of this endothermic heat is important as by this process sufficient heat energy reaches the deeper layers during activation to cause coagulation. Since coagulation is a time- and threshold-dependent process, there exists a quasi-homogeneous zone of reaction beneath the active electrode due to the direct current interaction and consecutive heat conduction (no. 3 in Fig. 4.2). The depth of coagulation is equivalent to the diameter of the applied coagulation tip or to the contact surface with the tissue. If, on the other hand, the current duration is only short, the resulting coagulation depth is less deep.

The dimensions of the coagulation zone change under bleeding conditions, i.e. they increase as a consequence of the electrolytic conductivity of the blood layer.

Shape and dimension of the active electrode together with the current densities appearing in the tissue, the current duration and the motion of the active electrode determine the time-dependent temperature profile and thus finally the degree and extent of interaction. In addition, the HF energy delivered to the tissue depends on the so-called power characteristic, which is a function of the power setting and the ratio of the contact resistance of the applied active electrode to the respective internal electrical resistance of the HF apparatus.

Moreover, the type of HF current, i.e. the amplitude-time curve, which may be modulated or nonmodulated, has considerable influence. Thus it can be easily appreciated that a continuous so-called unattenuated HF current is necessary to perform HF cutting since this process needs a continuous energy supply (Fig. 4.4 a). This shape is sometime called "cutting current".

On the other hand, a strongly modulated waveform of the HF current, which is sometimes called "coagulation current", yields the most effective haemostastis and necrosis (Fig. 4.5).

Provided the voltage amplitude is increased (Fig. 4.6 a), the active electrode may be positioned at a certain distance above the tissue and a tree-like cluster of sparks or arcs sprayed onto the tissue surface. This underlies the principle of fulguration which has gained great popularity mainly in the United States where it is referred to as spray coagulation. The arcs exhibit a temperature of about 600°–1000°C and have a pale violet colour. The heat produced results in a superficial dehydration of the tissue, which is usually accompanied by charring. The advantage of spray coagulation, which is best applied in a rotary motion across the tissue surface, is the production of haemostasis without adherence of the probe to the coagulated tissue.

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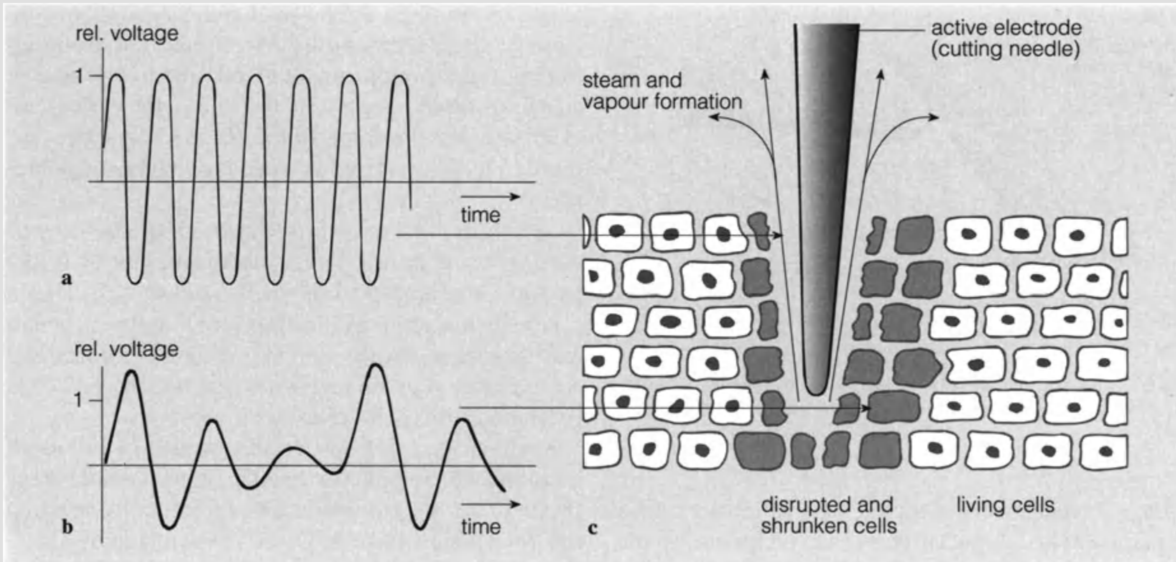
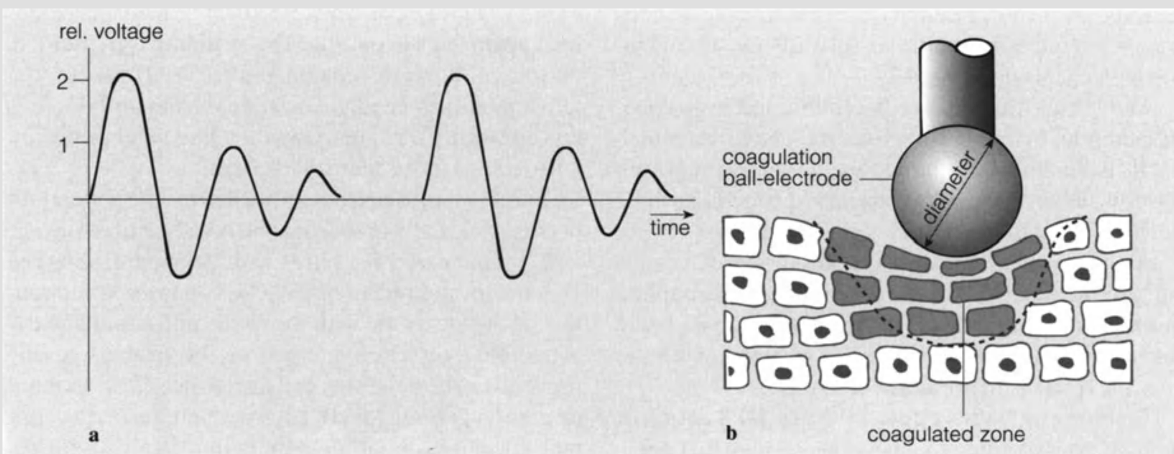
Fig. 4.4 a–c. HF cutting. **a** Unattenuated and unmodulated current; **b** moderately damped and modulated current; **c** cutting principle

Fig. 4.5 a, b. HF coagulation. **a** Strongly attenuated and modulated current; **b** coagulation principle (soft coagulation)

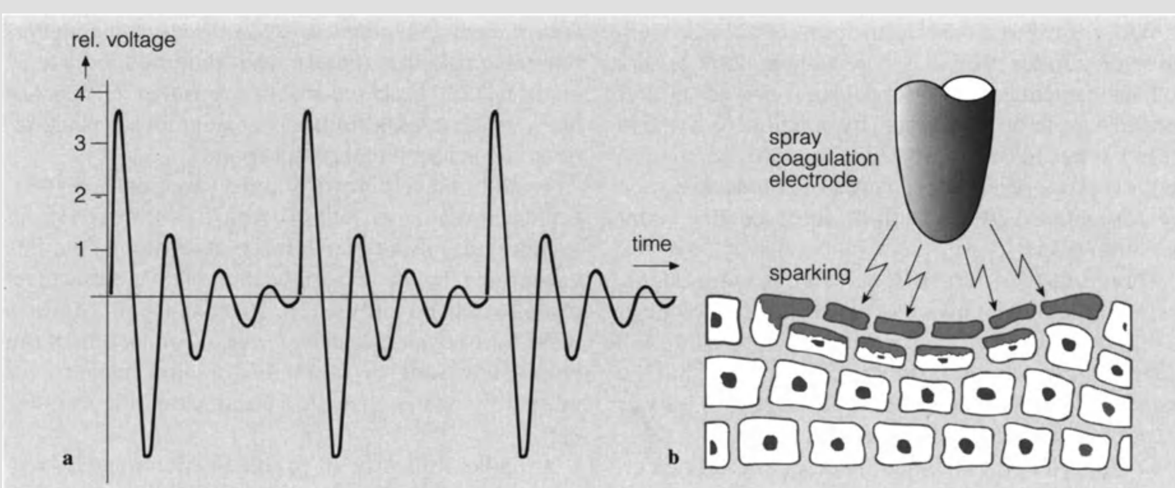
Fig. 4.6 a, b. Fulguration and spray coagulation. **a** Highly damped and modulated current; **b** principle of spray coagulation; this is dangerous and should not be used in ES except in association with argon beam


rel. voltage
1
time
a
rel. voltage
1
time
b
steam and
vapour formation
active electrode
(cutting needle)
disrupted and
shrunken cells
living cells
c

4.4


rel. voltage
2
1
time
a
coagulation
ball-electrode
diameter
b
coagulated zone

4.5


rel. voltage
4
3
2
1
time
a
spray
coagulation
electrode
sparking
b

4.6

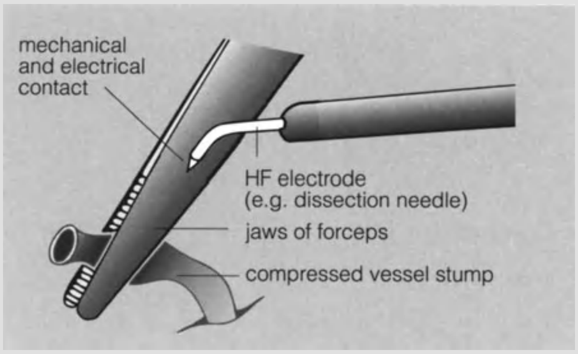


Fig. 4.7. Principle of coaptation coagulation by mechanical compression and electrical energy with jaws of forceps

Spray coagulation requires a relatively high impedance, i.e. a special power characteristic of the HF apparatus is necessary.

In general surgical practice, haemostasis is best achieved by the intermediary use of clamps or forceps to achieve coaptation of the vessel walls, i.e. a coagulation with coaptation (Fig. 4.7).

The vessel which has to be obliterated is grasped, for example, by the jaws of forceps. The effect which results is similar to a welding together of the opposing vessel walls as these are compressed together whilst the HF current is delivered.

In endoscopic procedures, obliteration of vessels can also be achieved when the HF current is applied directly onto the suction instrument or by simply touching any operative instrument in contact with the bleeding tissue with the active electrode.

Haemostasis results either by direct HF heating of the tissue surrounding the bleeding vessel with consequent shrinkage or by direct contact of the active probe with the vessel stump.

With regard to the different forms of active coagulation electrodes used, e.g. ball-shaped, hook or suction instruments, the optimal actual power settings needed have to be ascertained by practice. As a rule of thumb, it has to be remembered that the coagulation depth is proportional to the area of contact between the respective active electrode and the dry (non-bleeding) tissue.

Therefore the necrosis zone extends more deeply when a large suction tip is used as distinct from the relatively small contact area in the case of a thin hook electrode. In the latter instance, there is a risk that the tissue is cut before coagulation is achieved if the power setting is not reduced sufficiently.

Compared to the coagulation electrode, a fine cutting electrode results in such a large current density ahead of the tip in the tissue that a very rapid locally circumscribed temperature rise occurs. The resulting boiling and vapour pressure of the cell fluids produces an explosion-like rupture of the cells in the path of the electrode. At the same time, the cut edges become more or less coagulated as a result of the heat conduction.

In addition to the RF power used, the efficacy of cutting coagulation is determined by the cutting velocity and the geometrical shape of the electrode. Thus a relatively low HF power setting combined with a high cutting velocity results in weakly coagulated cut edges; coagulation is enhanced when higher RF power is combined with a slow rate of cutting.

Knife-shaped HF electrodes yield very smooth incisions when applied along the sharp end, whereas they can be used to produce coagulation by pressing the broadside of the knife onto the bleeding tissue plane.

Because of the much smaller heat capacity compared to knife electrodes, needle and wire electrodes heat up during HF cutting. This results in a greater risk of adherence to the coagulated tissue. However, the movement of a needle electrode during an HF cut is less constrained compared with a knife electrode, i.e. it provides a more controlled effect.

Band or loop electrodes are ideal for the generation of concave cuts, e.g. shaving and levelling of tissue.

To avoid extensive burns with delayed healing the HF current should not be switched on prior to the contact of the electrode with the tissue and should be deactivated soon after removal of the probe, thereby preventing the generation of arcs which cause extended carbonization. An HF cut may be regarded as optimal if the power setting results in a minimal arc between the RF electrode and the treated tissue.

Monopolar HF surgery may induce deleterious aberrant currents which cause overheating, under certain circumstances remote from the intended site of application. These secondary unwanted effects are likely to be evoked in areas of anatomical constrictions and at accidental contact points.

In addition, a faulty or slipped (poor contact) neutral electrode may result in extensive burns. To avoid such serious mistakes, several strict recommendations concerning the use and application of the neutral electrode have been formulated. These safety precautions include, for example, safe electrical connection of the neutral electrode, measurement of impedance irregularities on segmental neutral electrode configurations, etc.

In general, nearly all problems mentioned above may be avoided by the use of the *bipolar* system

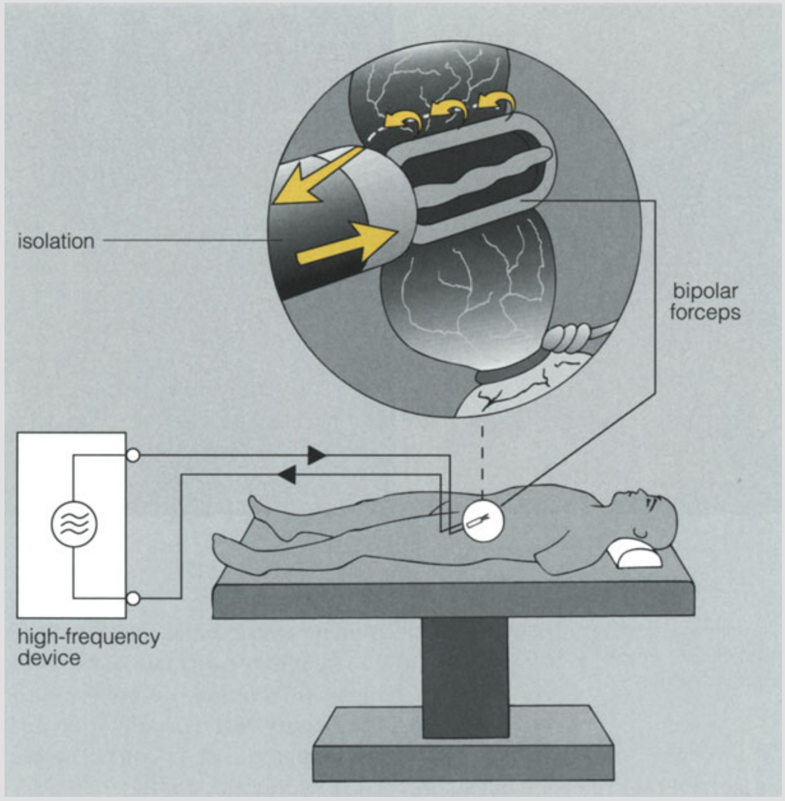


Fig. 4.8. Principle of the bipolar HF surgery (e. g. coagulation of adhesions) (*yellow*)

(Fig. 4.8), since the interaction is then restricted to the direct vicinity of the applied bipolar electrode. Now that the realization of a bipolar coagulation probe has been achieved despite the technological difficulties, the system should be favoured over monopolar coagulation in view of its increased safety.

The development of bipolar HF cutting has proved more difficult, but the effort in resolving the problem should continue as it would considerably enhance the overall safety of HF surgery.

Conventional HF surgery, specifically when used to control bleeding by RF coagulation, often results in extended thermal damage, which may be accompanied by an immediate or delayed risk of perforation of hollow organs. In addition, smoke generation is inevitable, and this obscures visual control and the frequent adherence of the coagulum to the electrode may precipitate renewed bleeding as the instrument is withdrawn. These well-known disadvantages of traditional HF surgery have stimulated various developments in an effort to minimize or prevent them.

One very simple development which eliminates these disadvantages is electrohydrothermia (EHT; or electrohydrothermic surgery). In this system, a liquid jet (distilled water), the flow of which is regulated, is instilled before and during the HF current flow onto the site of interaction (Fig. 4.9). As distilled water is almost non-conductive, besides diluting the escaping blood, it prevents overheating of tissues by the combined effect of washing of electrolytically conductive body fluids and external surface cooling. Thus, within the zone of interaction, the temperatures remain just below the liquid boiling point, i. e. at about 100°C. This is partly caused by the "energy consumption" at evaporation.

An EHT-produced coagulation is noticeable by its typically pale surface colouring (nos. 4, 5 in Fig. 4.2; Fig. 4.9). In addition, the three-dimensional extension of the necrosis zone is smaller compared with the one achieved with conventional HF coagulation. Thus the risk of perforation in hollow organs is reduced further. By the incorporation of a miniaturized spring into the probe tip, the strain pressure (which reduces the wall

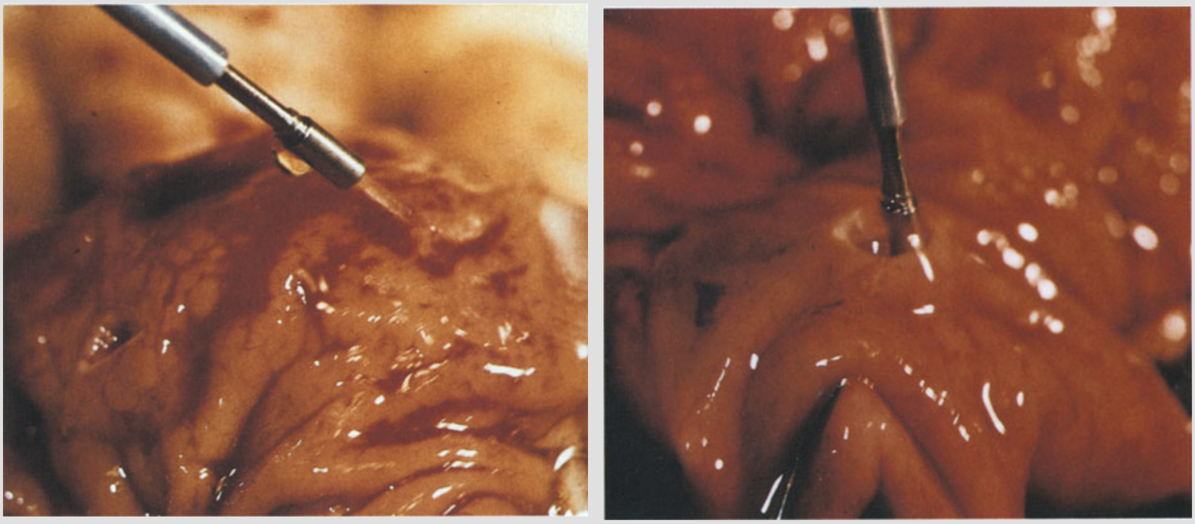


Fig. 4.9. Electrohydrothermia (electrohydrothermic surgery, EHT); *left*, liquid instillation before coagulation; *right*, EHT coagulation with simultaneous instillation

thickness of, for example, hollow organs by mechanical deformation to a dangerous level) is reduced, whereby the EHT application is rendered even safer.

The EHT technique does not constitute a different ancillary technology to the well-known HF surgery but a modified one. To operate such a modified system one needs a roller pump, a control unit and a two-stage foot switch which guarantee that distilled water is splashed from appropriate nozzles onto the respective site of treatment before the intrinsic HF current interaction is activated.

Up to now the clinical application of the EHT probe has been in the endoscopic control of gastrointestinal bleeding, but its potential has been demonstrated experimentally, for example, in transanal rectal surgery.

For the coagulation of vessels in the endoscopical dissection of the oesophagus, bipolar coagulation tweezers have been developed on the EHT principle and have been applied successfully in the experimental setting (Fig. 4.10).

Stimulated by the positive practical experience with EHT coagulation, a liquid-assisted HF cutting technique has been developed, namely electrohydrothermic cutting. All HF cutting electrodes may be modified for simultaneous liquid instillation. For dissections, needle electrodes made from highest melting point materials such as tungsten or molybdenum have stood the test of time. The needle electrode can be either surrounded by a hollow cylindrical tube or manufactured as a hollow with the hole placed in the vicinity of the needle tip to serve as the liquid outlet. Figure 4.11 shows one example for dissection with EHT needle electrodes.

Laser

A further thermal method is based on the local absorption of electromagnetic energy with secondary transformation into heat. For this purpose microwave and laser radiation are used. While the application of microwave radiation for coagulation purposes has been demonstrated experimentally and is even available as a commercial version of a microwave scalpel with excellent cutting properties, it is the application of laser radiation which has largely dominated the scene.

Fundamentally, the interaction of laser radiation with biological material may result in photochemical, photothermal and photoionizing processes. They depend especially on the time of exposure as well as on power and/or energy density. Thus a reaction caused by laser radiation may be achieved either by thermal or ionizing means.

With regard to the thermal effect, the extension and the degree, e. g. coagulation, carbonization or vaporization, are especially dependent on the optical and thermal properties of the irradiated tissue, the irradiation spot size and the exposure time, as well as on the power or the energy delivered by the laser radiation and its respective wavelength.

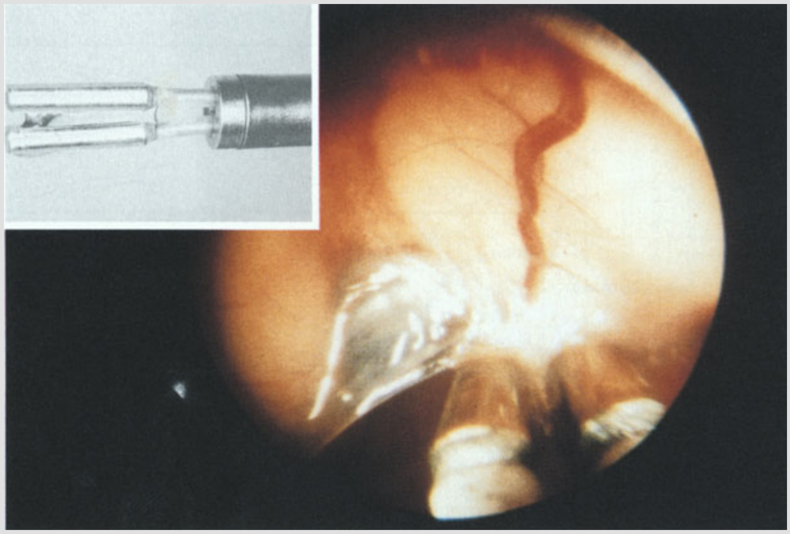


Fig. 4.10. Vessel coagulation with bipolar EHT tweezers (*inset* shows the liquid drop between the two tweezer halves, which may be retracted in the instrument)

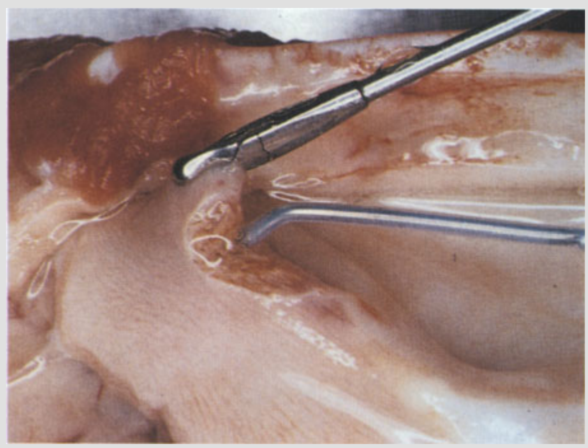


Fig. 4.11. EHT dissection, microlaryngoscopical application of an EHT needle electrode

Non-thermal interactions such as photoablation and photodisruption or fragmentation are achieved with pulsed lasers. These cause photodissociation and plasma formation which are responsible for a mechanical levelling (ablation) or rupture of tissue.

Photoablation is mainly established at pulse durations in the microsecond region, i.e. below the thermal relaxation times of biological material. If the absorption of laser radiation is high enough and happens in such short times that photodissociation commences, i.e. chemical bonds became separated as a consequence of large electrical field strength, a dielectric breakdown results. As a result, the kinetics of plasma formation together with the very rapid absorptive heating of the material lead to a superficial removal, i.e. the tissue is ablated in layers of several micrometres.

If one proceeds to even shorter exposure times, i.e. nanoseconds or less, an optical breakdown happens – even in transparent material – which is causally accompanied by plasma formation, a cavitation bubble and the secondary release of a shock wave. This effect may be applied to perform, for example, laser lithotripsy where stones may be disrupted, or to destroy opaque membranes located, for example, in transparent media.

Both effects, i.e. photoablation and photodisruption, are threshold-dependent effects and may be achieved with different types of laser, e.g. excimer- (at about 200–300 nm), neodymium-yttrium-aluminium-garnet (Nd: YAG; 1.06 μm), holmium-YAG (Ho: YAG; 2.1 μm) or erbium- YAG lasers (Er: YAG; 2.94 μm).

The different wavelengths which are available today go from the ultraviolet up to the far infrared region. It was recognized very soon after the first technical realization of a laser by Maiman in 1960 that optical radiation in the form of laser light may be transmitted, especially in the visible and near infrared spectrum through flexible light guides. These transmission systems are based on the physical principle of total internal reflexions, where the light is guided by criss-cros-

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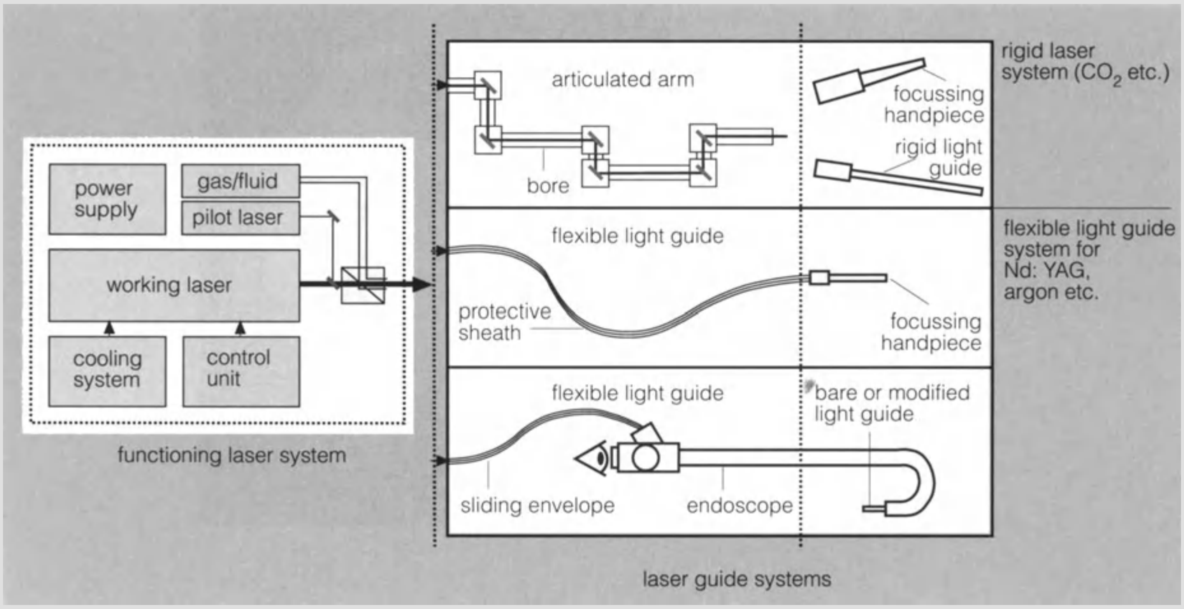

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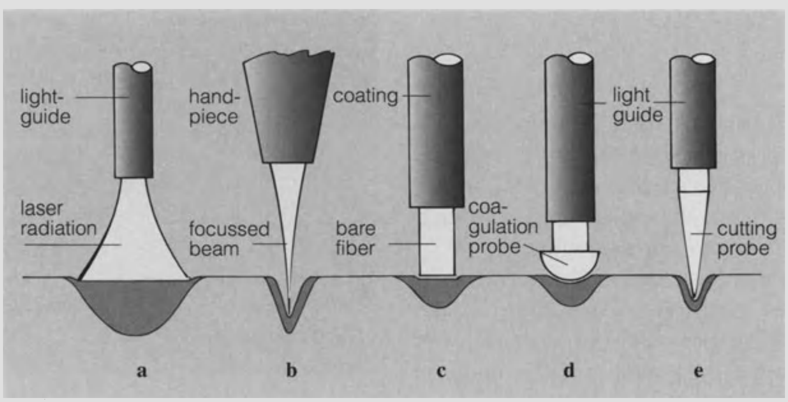


Fig. 4.12. Different transmission systems for laser radiation

Fig. 4.13 a–e. Different laser applicators. **a** Non-contact coagulation; **b** focussed beam; **c** bare fibre; **d** coagulation tip; **e** cutting probe

sing the core of a two-layered cylindrical structure from the proximal to the distal end. The combination of a laser source and a light guide yields a nearly ideal endoscopical surgical system which may be applied in a non-contact mode (Fig. 4.12).

One of the main indications of laser radiation applied by the non-contact mode is control of bleeding. For cutting or removal of tissue and, in addition, the possibility of focussing the laser beam by lenses integrated in a focussing handpiece placed at the end of a flexible light guide or an articulated arm (Fig. 4.12), there is the option to work with bare fibres in contact with the tissue or to mount various contact tips onto the distal end of the light guide (Fig. 4.13).

With bare fibres and contact tips, a much lower laser power is necessary to perform the desired effect, and therefore smaller and cheaper laser units may be used. While bare fibres almost always result in a contact diameter which reflects that of the optical fibre and is very seldom shaped to a cutting tip, contact probes can be fabricated in various shapes such as coagulating ball tips or cutting cones or blades. The probes themselves are made either from highly heat-

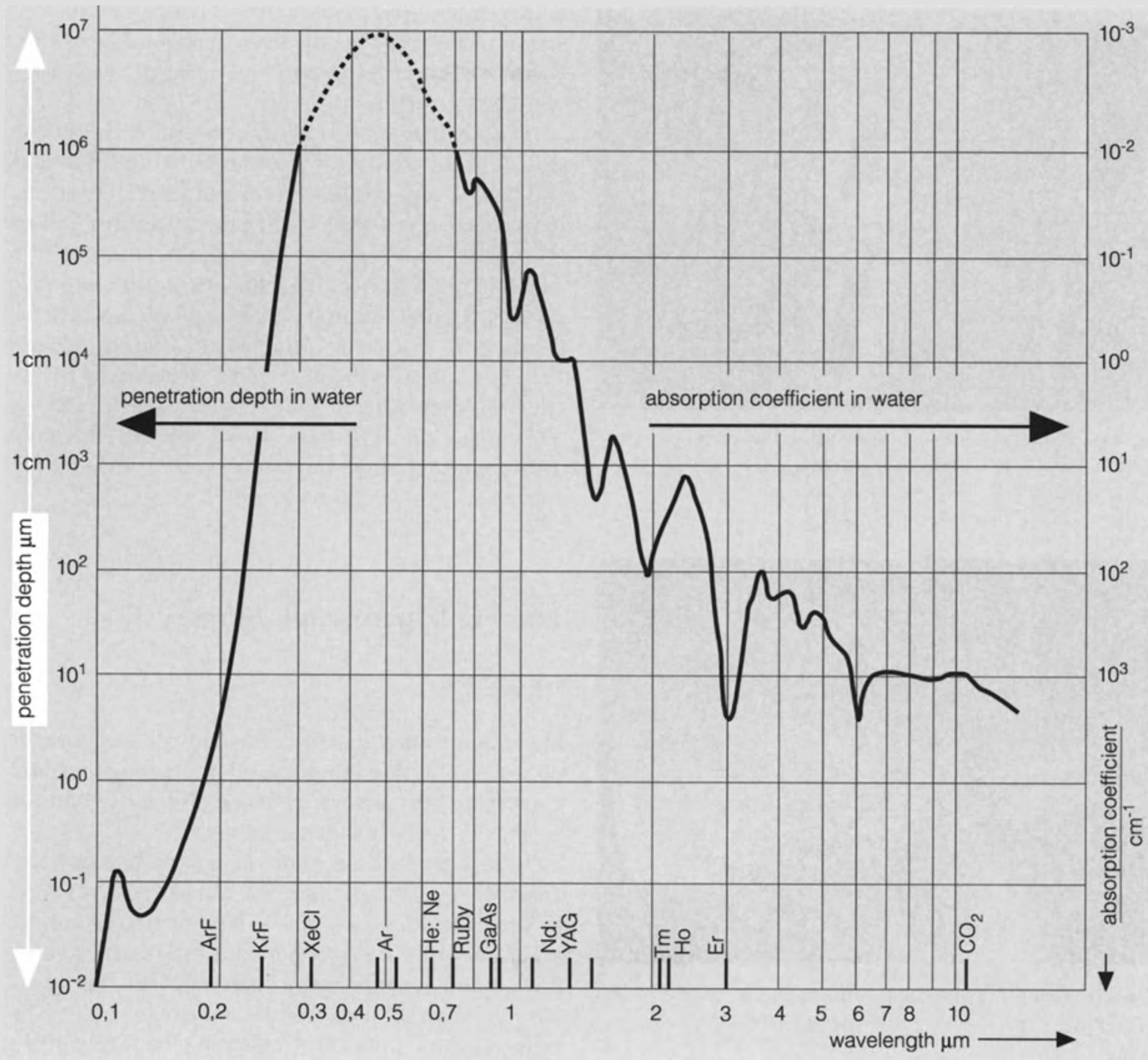


Fig. 4.14. Wavelength-dependent absorption and penetration depth of water and haemoglobin

conducting sapphire or glass ceramics. To perform coagulation combined with cutting capabilities, the probes may be frosted at the respective sides. The scope of different laser applications has thus increased by the various manipulations at the distal end of a transmission system where sometimes even metallic probes become heated, as in one special form of laser lithotripsy or laser angioplasty.

The thermal reactions of the tissue as a result of laser irradiation are essentially influenced by the absorption characteristics of water and haemoglobin (Fig. 4.14). Therefore, the explanation why a CO_2 laser at an emission wavelength of 10.6 µm is well suited to perform clean cuts in tissue with a high water content is easily understood by the extremely small depth of penetration in water.

From the numerous laser systems which may be applied medically, three types exhibit specific characteristics which determine the respective coagulation (nos. 7–9 in Fig. 4.2) and cutting properties (Fig. 4.15).

While CO_2 laser radiation at a wavelength of 10.6 µm is strongly absorbed and penetrates only slightly into tissue with a higher water content (Fig. 4.14) and therefore yields only superficial coagulation in a defocussed beam (no. 9 in Fig. 4.2), this radiation is the first choice for classical laser cuts

Fig. 4.15. Typical laser cuts in liver tissue achieved by *1*, CO_2; *2*, Nd: YAG; *3*, argon-ion laser radiation (from left to right)

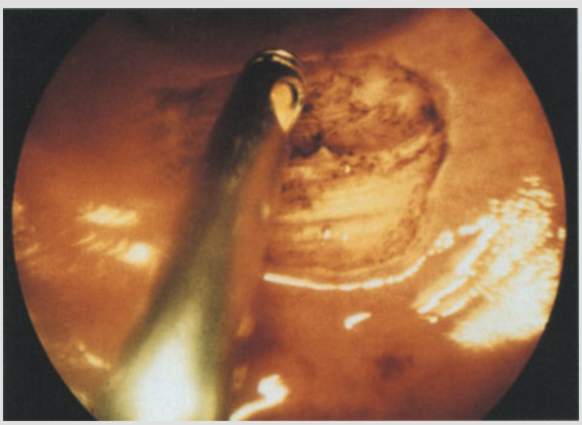


Fig. 4.16. Dissection procedure with CO_2 laser radiation and a rigid hollow wave guide with a deflecting mirror

(Fig. 4.15). Although fully flexible light guides are still in the experimental stage for this wavelength, rigid hollow wave guides with or without a deflecting mirror are available for use with CO_2 lasers to perform dissections (Fig. 4.16). Nd: YAG laser radiation at a wavelength of 1.06 μm penetrates relatively deep into biological tissue and is characterized by a considerable scattering, thereby causing mass coagulation results (no. 8 in Fig. 4.2) with only moderate cutting properties (Fig. 4.15).

A poor absorption in water but significantly higher absorption in haemoglobin is characteristic of the radiation of an argon-ion (Ar) laser in the green-blue part of the visible spectrum (Fig. 4.14), with the two dominant laser lines at 488 and 514.5 nm. Therefore, an almost wavelength-selective coagulation may be achieved in strongly vascularized tissue, and the outstanding possibilities to focus such relatively short wavelength laser radiation make sharp cuts feasible with this type of laser too (Fig. 4.15).

The wavelength selectivity concerning the absorption dependence may be further enhanced if tunable dye lasers are used. With reference to the absorption in water, the Er: YAG laser at a wavelength of 2.94 μm shows outstanding properties since this laser line coincides almost exactly with a water absorption peak (Fig. 4.14) located at about 3 μm. Therefore this laser recently proved to be a suitable candidate to perform very fine cuts; this might only be exceeded by the excimer laser, which emits in the ultraviolet region, e.g. 193 nm for the ArF and 248 nm for the KrF laser. These cutting properties are essential in hard substances such as bones and dentine.

Laser in Laparoscopic Surgery

J. Keckstein

Laser usage has expanded enormously during the past decade, in ophthalmology, otolaryngology, neurosurgery, plastic surgery, gastroenterology, dermatology and particularly in gynaecology.

Lasers provide an aura of high technology with emotive appeal to the surgeon and patient. Nevertheless laser irradiation offers a high degree of surgical precision with varying combinations of cutting, vaporization and coagulation properties. Although its use has been the subject of great controversy, there are substantial scientific data indicating the value of laser especially in endoscopic surgery.

Surgical lasers for laparoscopic surgery include the CO_2, argon, KTP, and Nd: YAG lasers.

CO_2 Laser

The CO_2 laser is the most commonly used instrument for vaporization to achieve either ablation or excision in laparoscopic surgery.

This laser has an infrared wavelength of 10.6 μm which is invisible. A milliwatt red helium-neon laser is usually used as a guide beam for aiming the CO_2 beam. The CO_2 laser is capable of a very small spot size, i.e. it may be focused to a 0.20 mm minimum spot.

Properties: The laser light is absorbed by nonreflective solids and liquids, especially water-containing tissue.

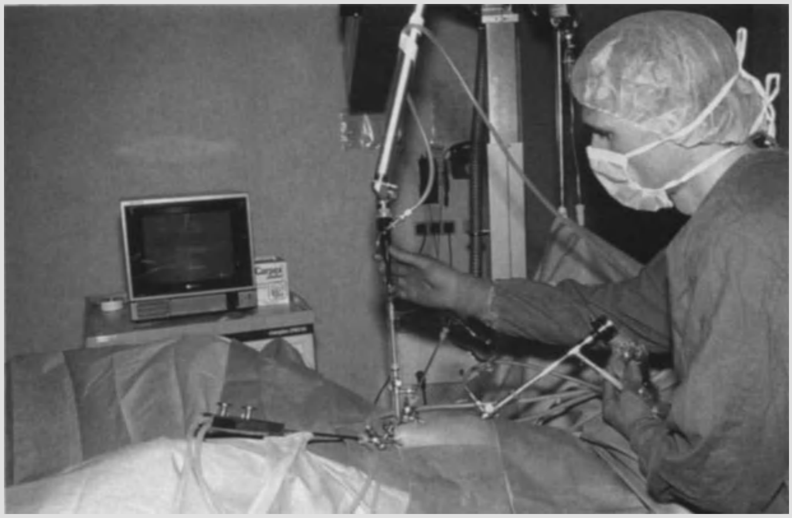


Fig. 4.17. Use of CO_2 laser for laparoscopic surgery. Rigid mirror-arm is attached to the second-puncture probe

The laser power is absorbed in the first 100 µm. The absorption is not dependent upon the colour of the tissue. Although the CO_2 laser is predominantly a vaporization laser, it can also be used for surface coagulation.

Technical Aspects: The present endoscopic delivery systems for the CO_2 laser are somewhat cumbersome and technically difficult to manipulate because of the necessity of firing the CO_2 laser beam through air or gas media. Although modifications of the CO_2 laser instruments have been developed, at the present time only two systems for laparoscopic CO_2 laser are suitable for clinical application:

The laser beam can be introduced through an operating laparoscope (single puncture) or through a second trocar (Fig. 4.17). The only advantage of the single puncture route is enhanced safety, the laser beam being constantly in view.

The main advantages of the second puncture method are ease of manipulation of the laparoscopic handpiece and the possibility of many different treatment angles of the incident laser beam.

CO_2 laser vaporization produces a large amount of smoke that can absorb CO_2 laser energy, induce moisture on the lens and the mirror and reduces the visibility. The smoke must be removed from the peritoneal cavity during the laparoscopic procedure with a special smoke evacuator.

The advantages of CO_2 laser irradiation include:
- Diseased volumes can be vaporized under precise visual control ("you get what you see").
- There is no mechanical contact with the intended target.
- Heat propagation to adjacent tissue is minimal.
- Microorganisms at the impact site are automatically destroyed.
- Vessels smaller than 0.5 mm will be thermally sealed.

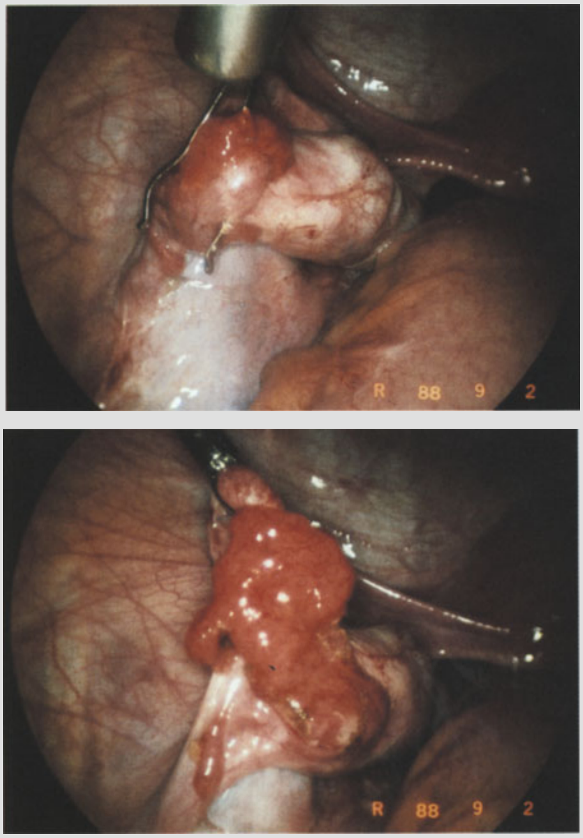
The disadvantages are:
- Rigid delivery systems
- Smoke production
- Limited coagulation effect

Clinical Use. Due to its specific properties, the CO_2 laser represents an excellent tool for incision of delicate sites. Extensive adhesiolysis of bowel or other organs may be performed without the danger of unexpected damage to adjacent tissue (Fig. 4.18a, b) The limited haemostatic effect of CO_2 laser necessitates the use of other coagulation modalities such as electrocoagulation with the HF generator.

Fiberoptic Lasers

Argon Laser and KTP Laser

The KTP (potassium titanyl phosphate) laser and the argon laser generate visible light. The argon laser produces up to 10 lasing wavelengths in the blue-green



a

b

Fig. 4.18. **a** Distal occluded tube. Incision with the CO_2 laser. **b** Tubal ostium after laser incision

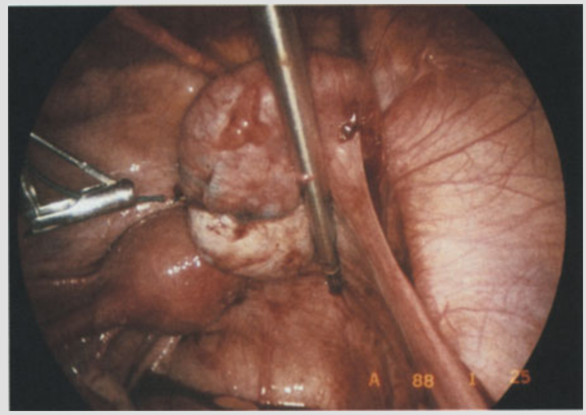


Fig. 4.19. Laparoscopic use of argon laser. Opening of distal occluded, distended tube with the bare fibre

portion of the spectrum. The most prominent wavelengths are at 514.5 nm and at 488 nm. The KTP laser light is of lime-green colour (532 nm). These wavelengths result in the greatest absorption occurring in pigmented and haemoglobin-containing tissues. They are not absorbed by clear tissues or fluids.

Properties. Tissue penetration of Argon and KTP-laser does not exceed 2 mm, and vaporization and incision are possible with high power densities accomplished by using smaller fibres and close approximation to the tissue. Argon can coagulate tissues effectively at low power densities and produces excellent haemostasis.

Technical Aspects. This laser light can be transmitted through flexible fibres into the peritoneal cavity. It is possible to direct the laser beam on nearly any site in the peritoneal cavity. The flexible fibre can be used in the contact or non-contact mode. The main advantage of the free beam non-contact mode is the large range of angles of delivery during the operating procedure. The benefits of the contact mode include tactile feedback, more controlled laser application and reduced risk of inadvertent damage to tissues due to temporary misdirection of the laser beam. For laparoscopic surgery the laser light is transmitted through a 300-, 400-, or 600-μm fibre (Fig. 4.19). The fibres can be used repeatedly. Worn tips can be cleaved with a knife or special cleaving instrument.

One of the disadvantages is that the green aiming beam may be difficult to see unless the fiber tip is brought very close to the tissue. During the procedure it is necessary to work with safety filters in order to protect the operator's eyes and control the tissue effect. In addition this laser requires a high electrical power density.

Nd: YAG Laser

The Nd: YAG laser is a solid-state laser. The delivery system is similar to that of the argon and KTP lasers.

Properties. This laser has the greatest penetration and coagulation effect resulting in deep heating (Fig. 4.20). The laser penetrates up to 4 mm and thus produces excellent lateral coagulation. This is useful in controlling haemorrhage from ulcers and from lung and bladder tumours. This laser does not cut well even at high power densities.

Technical Aspects. The use of Nd: YAG laser for laparoscopic surgery has been reported by various authors, but has never been approved by the Federal Drug Administration (FDA) because of the risk of injury to vital structures by the unfocused Nd: YAG

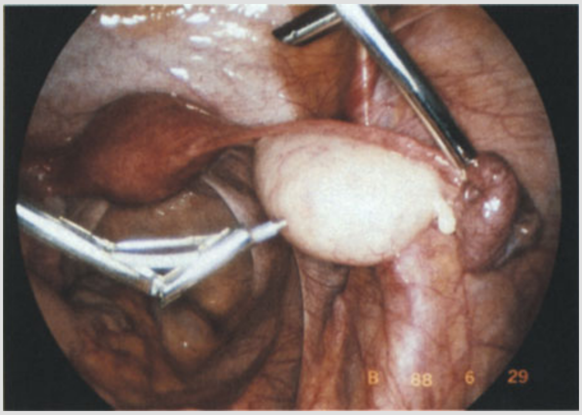


Fig. 4.20. Coagulation of polycystic ovary with the Nd: YAG laser in non-contact technique

laser beam. Placing the fibre in direct contact with the tissue results in heating of the tip. Due to this effect, cutting with the Nd: YAG laser in contact with the tissue becomes possible.

Problems arise when dissecting tissue with the bare optical fibre, because damage to the fiber may occur. The use of focusing tips made of sapphire that allow contact use of Nd: YAG energy has led to wider use of this laser in laparoscopy. However, this method is technically expensive and requires detailed instruction of the user. In addition, cooling of the sapphire tip is necessary and bears the risk of gas embolism for the patient.

A new laser system Fibertom (MBB, Munich-Ottobrunn) has been developed for contact surgery. It allows accurate tissue effect and offers several advantages (no cooling necessary, fibre is protected against thermal damage etc.).

The advantages of Nd: YAG laser include:
- Delivery to the tissue easy
- No need for security systems
- Efficient coagulation effect
- Coagulation and incision possible with the same system
- Minimal smoke production
- Laser beam passes through fluid

The disadvantages are:
- Safety eye filter necessary
- Damage to the delivery system possible (except Fibertom)
- Need for water cooling and high energy supply

Clinical Use. Almost every procedure that has been done laparoscopically with scissors, cautery and CO_2 lasers can be carried out using Nd: YAG lasers.

Summary

Lasers now have an established place in laparoscopic surgery. They offer unique advantages and a high degree of surgical precision with varying combinations of cutting, vaporizing and coagulation properties. In the hands of an experienced surgeon laser irradiation appears safe and effective. Laser use has been a major technical advance in laparoscopic surgery.

To date, laser instruments have proved to be safe, with only a handful of misadventures reported.

Comparison of Various Methods

Viewed from a purely financial standpoint, the laser is inferior to the other ancillary technologies. That is, the application of simple cautery has often proved to be completely adequate. HF surgery is likewise relatively simple and, besides being inexpensive, has a proven efficacy as an ancillary technology in the conduct of ES. In addition to Figs. 4.11 and 4.16, Fig. 4.21 represents a visual comparison of laser versus HF surgery in the dissections involved in ES.

The several possibilities which might be attained by the use of a laser have, up to now, not been fully realized experimentally, although a number of applications have been established. It is a pity that the various characteristics of the different lasers cannot be combined in one system. Nevertheless, laser radiation cannot be ruled out as an important ancillary technology

Fig. 4.21. Experimental comparison of the cutting characteristics in the larynx. *Left,* CO_2 laser irradiation; *right,* EHT surgery

in endoscopic surgery in the future, particularly with the development of tunable diode array lasers (see Chap. 26).

Moreover, there exist other technologies such as the hydrojet and ultrasound dissection which may be successfully applied in special cases. These are currently under evaluation in a number of centres for the execution of ES procedures.

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5 Requirements for an Endoscopic Surgery Unit

G. Buess and A. Cuschieri

Current Problems

Endoscopic Surgery (ES) is rapidly becoming an accepted concept in everyday clinical practice. For the surgeon and operating team, it means the application of new technologies that must be integrated into existing structures.

Surgical Instruments

The surgical instruments for ES can be handled in much the same way as conventional instruments, except that their space- and material-saving design makes them more delicate and adds to the difficulty of instrument layout.

ES instruments should be stored and transported in sturdy containers. Preferably the instruments should be stored in separate compartments within the container so that they will not be damaged during storage and transport. To avoid the frequent resterilization of instruments that are used only occasionally, the containers should house only instruments that are used in every procedure. Instruments for special situations are individually sterilized and used only when needed.

Peripheral Devices

A major problem concerns the handling of the peripheral devices that are essential for ES. Four basic problems are encountered:

- *Optimum placement of the monitors.* This is an important prerequisite for ES. The monitors should be close to the surgeon without restricting his or her mobility, and they should be height-adjustable.
- *Ill-defined sterile/nonsterile junction points.* Numerous tubes and cable attachments are usually required, but with present-day equipment, each connection is likely to have an ill-defined junction point at which the nonsterile part of the connection from the peripheral device enters the sterile field. There is a danger that nonsterile portions of a connector may be drawn into the sterile area.
- *Tangled connecting cords.* Many of the tubes and cable attachments are connected to the operating instruments and are coiled up on the instrument table or hang between the table and the operative site. The cords become tangled during the procedure, and unless the surgical nurse constantly straightens them out, the situation can become chaotic.
- *Monitoring and controlling the peripheral equipment.* The peripheral devices are often arranged so that their indicators cannot be easily seen. Usually the devices are attended by a third party.

Setup of a Modern ES Unit

Satisfactory solutions to the above problems cannot be achieved with currently available equipment, so for the time being, compromisses still have to be made. For the future, sophisticated developmental groundwork remains to be done in order to achieve effective solutions.

The setup of the ES unit should be such that all the ES procedures presented in this book can be carried out. This requires a certain flexibility.

Arrangement of the Monitors

Monitors must be placed in the line of sight of the operating team and positioned so that they can be seen while the team maintains a physiologic working posture. The team members stand opposite each other in laparoscopic procedures, so at least two monitors are required.

The simplest solution is to place a large monitor on a video cart, although this does not allow for height adjustment. A second, small monitor is mounted on a mobile, height-adjustable stand (Fig. 5.1).

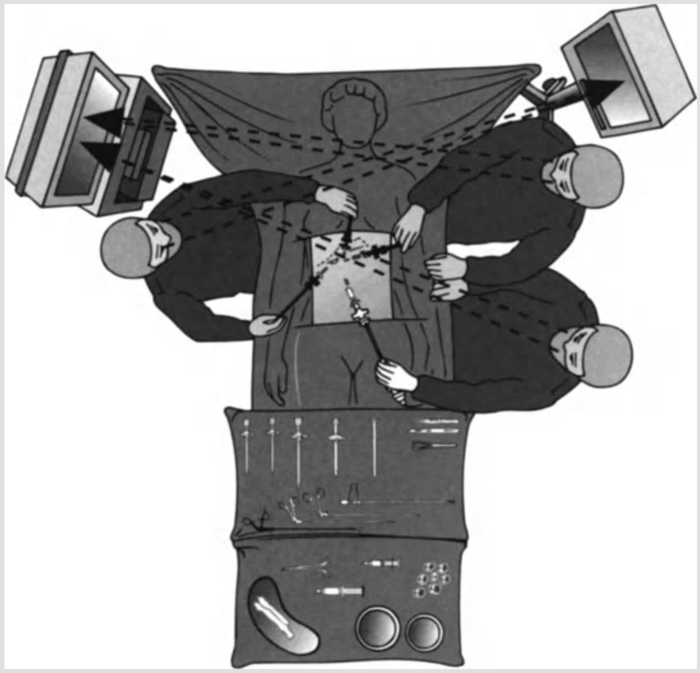


Fig. 5.1. The simplest method of positioning two monitors. The large monitor stands on the video cart where it can be seen by the surgeon. The small monitor is placed on a height-adjustable stand

The ideal arrangement is to place the monitors on two ceiling-mounted fixtures that are at the center and to one side of the operating table so that they do not interfere with overhead operating lights (Fig. 5.2). With this arrangement, the monitors can be adjusted to positions ideal for each procedure, and there are no floor-mounted stands to restrict the mobility of the operating team.

Arrangement of the Peripheral Equipment

The peripheral equipment should be arranged in two mobile blocks, with one cart carrying the video equipment and light source and a second cart carrying the high-frequency unit, gas expansion unit, and suction-irrigation system. Some free space should be left for adding equipment as needed. If a laser is used, current techniques require the use of an additional mobile cart.

Securing the Tubing and Cable Connections

All connecting lines must enter the sterile field at a designated site, where they are secured with adhesive tape or clamps to prevent slipping.

Concepts for an ES Unit of the Future: Monitoring and Control of Auxiliary Equipment

A monitoring and control panel mounted on an overhead fixture should be positioned at a suitable site in the operating field; the best site in laparoscopic procedures would be between the surgeon and the anaesthetist. Essential data should be continuously displayed on the panel, and additional information should be able to be called up as needed.

The peripheral equiment should be controlled directly by the operating team by means of switches. This could be made possible by draping the monitoring/control panel with a sterile, transparent plastic sheet. One advantage of this setup would be that the monitoring portion of the panel could alert the team at once to any problems that arise, much as in the cockpit of an aircraft. Of course this would require appropriate visual and acoustic warning signals. Direct control

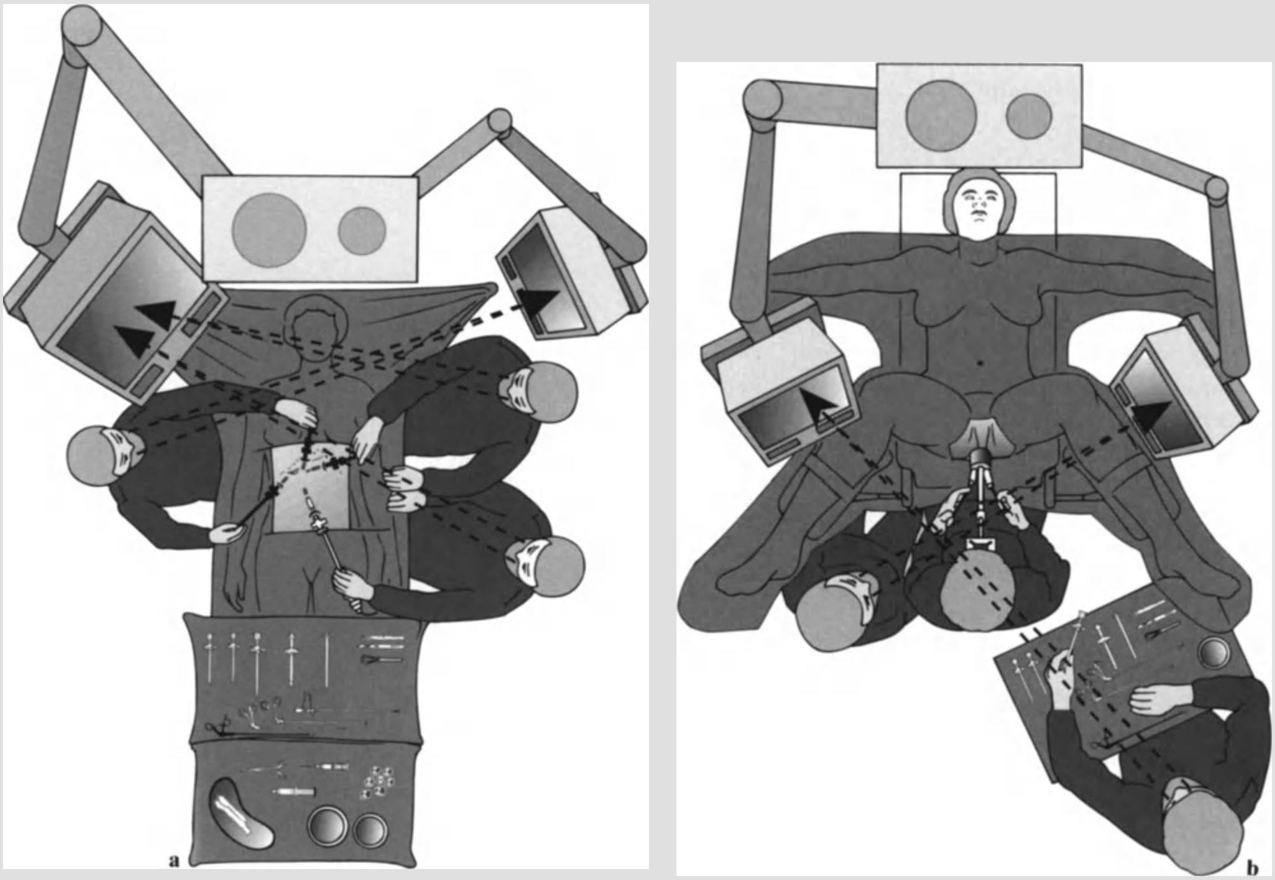


Fig. 5.2 a, b. The ideal method of positioning two monitors. The monitors are mounted on height-adjustable ceiling fixtures on both sides of the operating table and can be freely adjusted to the optimum position for a given ES procedure. **a** Position for laparoscopic cholecystectomy; **b** position for TEM

of the devices by the operators would avoid transmission errors of the kind that occur when equipment adjustments are made by a third party who may be inadequately skilled.

The hookup of cables and tubes to the peripheral devices should occur at a designated site within the sterile area to ensure that there is no sterile/nonsterile overlap, as occurs presently. One solution would be to place all the functions of the peripheral devices close to the operating table in the form of a hookup plate mounted on a ceiling fixture or cart. The hookup plate would be draped with sterile plastic film, and the lines connected to the plate through perforations in the film to preserve sterility.

Cable and tube placements should be as ergonometric as possible so that the connections to particular devices can be clearly identified and "tangling" does not occur. Connections that are not constantly functioning, such as the light and camera cables should be equipped with corresponding retrieval mechanisms.

6 Training in Endoscopic Surgery

G. Buess and A. Cuschieri

Introduction

Recently ES underwent dramatic development as a result of the unexpectedly rapid change in surgeons' attitudes concerning the feasibility of safe and noninvasive endoscopic procedures and also because of media-generated patient information. The widespread dissemination of the knowledge concerning the advantages of these techniques has caught the imagination of the public and surgeons alike in a short space of time. Most surgeons now acknowledge the benefits and are under pressure from their patients to apply these techniques in their own hospitals as quickly as possible.

The position in which most surgeons who are anxious to take up these ES procedures find themselves is less than satisfactory. Some surgeons will have sound training in endoscopy, but only few would have had prior experience in laparoscopic or thoracoscopic techniques. Operating using the video screen image is, in addition, a completely new experience.

With the introduction of ES in surgical practice, not only surgeons in training but also established surgeons face the problem of familiarization with completely new techniques and organization. New to the general surgeon are:

- Trocar access through the abdominal wall
- Insufflation of the peritoneum with gas
- Manipulation of miniaturized long-handled instruments
- Loss of tactile sense because of the inability to directly handle organs
- Working without direct vision and three-dimensional orientation
- Inability to insert large retractors
- Loss of direct hand manipulation

The last is a major disadvantage as the human hand with its multidirectional movement facilitates complex procedures such as suturing by allowing needle placement in any required direction. The equivalent exercise is much more difficult when performed endoscopically.

Many techniques used during conventional surgery cannot as yet be applied in ES. Others, e.g. underrunning bleeding vessels endoscopically, can only be performed with presently available needle holders. The reason is fixation of the instrument shaft by its access port. Development of instruments with a greater degree of freedom of movement is needed (see Chap. 2, p. 15). The requirement to train surgeons without prior experience in endoscopic work imposes an important challenge and logistic problems in providing sufficient surgical workshops.

The disparity between the number of experienced surgeons in ES and the number of surgeons who have to be trained necessitates the use of alternative new training methods.

Training for Conventional Surgery

The trainee surgeon starts with a rotational surgical training programme. Operations are learned by initially observing the procedure combined with assistance by holding retractors, then as first assistant and finally by performing operations oneself under the supervision of an experienced surgeon.

During this whole training period, gaining manual dexterity is usually confined to experience in the operating room. Only a small part of basic skills, such as knot tying, is learnt by practice on models.

The extent of innovation in conventional operative techniques, the instruments and technology used are acquired by the trainee during the apprenticeship period without the need for special workshops.

In Europe, surgical training courses have not played a large role in surgical education to date. However, with increasing subspecialization, a change has occurred. In Germany and the United Kingdom courses have been established in recent years with the emphasis on "hands on" experience and the acquisition of specific skills, e.g. anastomosis workshops, internal fixation of bones, microsurgery, etc.

Current Status of Training for ES

In the United States of America, where most of the techniques of ES were adopted following their development in Europe, there are established guidelines governing training in endoscopic surgery. All surgeons must complete a training course and obtain the necessary privileging before they can perform laparoscopic cholecystectomy (LC). The operative techniques used for LC are predominantly learned on laboratory animals, usually pigs.

In the United Kingdom training courses using animals are not allowed by law. Courses have been structured making use of lectures and videos for demonstration of procedures and results. Practical training is done by simulated operations on phantoms and in some instances assistance in theatre.

In Germany the Society for Surgery has defined guidelines for safe usage of these new techniques in clinical practice. In the United Kingdom the Royal Colleges have issued guidelines which specify the training and proctoring considered desirable for the setting up of laparoscopic surgery. In practice, training occurs by a combination of visiting specialized centres and 1–4-day practical courses. Prior to their clinical application, the surgical techniques have to be practised and mastered. In addition, team work is important in this type of surgery, and the necessary organization has to be established within the institution.

In our opinion there are two reasons against the use of live animals to gain this initial experience: (a) animal experiments are not justified if the experience can be obtained by other methods; (b) large animals require a lot of organization and are expensive.

There are therefore strong reasons for developing phantom models/trainers for procedures requiring the acquisition of new manual skills. The efficacy of the phantom-based exercises depends to a large extent on the didactic structure of the lessons and the realistic simulation provided by the model.

Over the last few years the Tübingen working group has developed training courses incorporating phantom models. Two years after the first clinical application of transanal endoscopic microsurgery (TEM) in 1985 (at that time at the University Department of Surgery, Köln-Lindenthal) we started TEM training courses. Comparable to training principles presented by Semm in 1986, a phantom was initially used, allowing the use of the endoscope and instruments under direct vision. In a graduated manner, increasingly complex steps of the operation are introduced to simulate closely the operation under endoscopic vision. Our system and Semm's have similar principles, but were developed independently of each other. We further refined our courses by introducing videos in 1986. The video system incorporates didactic principles for each step of training. The video tapes can also be reviewed later when the surgeon acquires the equipment. By this method video-supported training is possible.

In 1990 courses in laparoscopic surgery were established in Tübingen and Dundee along the lines of the TEM course, with graduated introduction of the complex steps of the operation to simulate closely the real situation.

Currently in Tübingen we hold weekly ES courses for nine or ten participants. Within a suitably equipped training centre, the phantom exercises are carried out by the participants after initial demonstration. These sessions are complemented by visits to the operating theatre to see the procedures. In addition there are lectures and discussions on the results of these ES procedures

Our manual training is coordinated by a non-clinical graduate scientist. The medical staff of the team cover the clinical aspects of the teaching programme. The equipment and initial financing of our training centre was supported by companies working in ES. Ongoing costs have to be met by a fee charged to participants. A similar advanced skills laboratory and teaching programme has been set up in Dundee.

Training for TEM

Conditions of Clinical Use

TEM enables the performance of procedures which range from local tumour resections in the rectum to complete sleeve resections, as well as rectopexy for rectal prolapse (see Chap. 24). Compared to laparoscopic surgery (cholecystectomy and appendicectomy), TEM has very specific clinical indications and is thus less frequently practised. The limited number of patients requiring this form of treatment makes clinical training difficult, and the restricted space available for manipulation within the rectum requires a high level of technical skill. For these reasons, TEM should be restricted to referral centres which attract a large enough number of operations. For training TEM we offer an introductory and an intensive course.

Introductory Course

The introductory course provides only a brief introductory account of the theory and technical aspects of TEM.

Theoretical Aspects

Instruments and devices, indications for resections of adenomas and early carcinomas, operative techniques, perioperative preparation and management of complications are the topics covered in the theoretical part of the course.

Practical Aspects

Manual training is in three progressive steps (see below). Each step is illustrated by a training video tape. The handling of the instruments of the enclosed phantom is only demonstrated at one workstation.

Aims of the Course

The course aims to demonstrate the operative techniques and complexity of the manual dexterity required. The surgeons thereby gain insight into whether they are able to carry out these complex techniques and whether they want to introduce the system in their hospitals. During the first two steps of training each participant has their own workstation. During the third step two surgeons share a single workstation.

Intensive Course

The intensive course is only available for surgeons who have the TEM instruments or have them on order, and who have already completed the introductory course. These rules were established because prior experience had demonstrated that only some of the participants on intensive courses were able to successfully introduce these operations in their hospitals. Furthermore, surgeons who set up the technique a long time after the course experienced problems which required further instruction and training.

Theoretical Aspects

- Instruments and devices: an intensive introductory account of the principles of the insufflation systems and diathermy is given
- Detailed presentation of the indications used for adenoma, early carcinoma and rectal prolapse
- Presentation of the technique and importance of endoluminal ultrasound in the rectum
- Explanation of the operative steps relating to the above using video sequences
- Perioperative management and treatment of complications
- Discussion of the clinical results

Practical Aspects

The practical exercises concerned with the training of the manual skills are arranged in a sequence of four steps (see below). Training video tapes are used extensively. The function of the ancillary devices/equipment is learnt by practice. Phases of manual training alternate with visits to the operating theatre to observe rectoscopic operations.

Aims of the Course

The chief aim is the instruction in all the surgical TEM techniques and teaching of clinical management. After completion of the course, a surgeon with sufficient talent for endoscopic microsurgery is qualified to introduce the technique clinically after further independent bench practice. Surgeons can obtain additional further training in their own hospital with the help of training video tapes. We recommend 20–30 h of bench practice by the surgeon before a clinical programme is embarked upon.

The Learning Programme

The participants are mostly trained surgeons who have limited experience of endoscopic surgery. Prior practical experience in microsurgery often proves helpful. For the beginner, operating directly from the video screen with a closed phantom is difficult. Consequently the didactic teaching programme is divided into learning steps.

Steps of the Learning Programme

- Manipulation of the endoscopic operating instruments allowing familiarization with the handles and long shafts.
- Coordination of two and then three instruments at any one time: because of the confined space available this is difficult in TEM.
- Dissection and suturing techniques.
- Familiarization with the stereoscopic endoscope with open and closed bowel.

- Working under insufflation: training is required for handling the insufflation and suction devices and the correct function of the seals.
- Adjustment of the instrument to obtain the best working position and exposure. The optical magnification depends on the distance of the object from the front lens. The correct position of the rectoscope is essential for the optimal working position.

Organization of Manual Training

Step 1: Transparent Plexiglas Rectoscope. Dissection of Cloth Phantom

After introduction of the operating instruments, coordination exercises are commenced on the Plexiglas rectoscope which has the same dimensions as the operating rectoscope (Fig. 6.1 a). Placed in the position normally occupied by the optics is a Plexiglas rod to simulate the space it occupies. A gap in the upper aspect of the rectoscope serves as a window for viewing the operative field. The transparent rectoscope allows assessment of the position of the instruments under direct vision, e.g., to recognize and avoid the clashing (sword play) of instruments.

Dissecting Exercise
A disc is cut out of the cloth using scissors and grasping forceps. Closure of the defect is then achieved by transverse continuous suturing (see Chap. 24).

Step 2: The Transparent Plexiglas Rectoscope. Dissection of Opened Bovine Bowel

Dissection and suturing of the bovine bowel is performed under direct vision (Fig. 6.1 b). The bovine bowel closely simulates the handling characteristics of human bowel.

Dissecting Exercises
Discs of 20-mm diameter are excised to practice submucosal and full-thickness resections. Closure of the defect using the transverse continuous suturing technique is then performed.

Step 3: Metal Rectoscope with Endoscope. Dissection with Opened Bovine Bowel

First, the stereoscopic endoscope is positioned in the optimal site within the rectoscope and then used to orient the rectoscope to the operative field (Fig. 6.1 c). The coordination of instrument handling under stereoscopic vision is then practised. Where difficulties arise direct viewing is also possible.

Dissecting Exercise
Dissection of bowel using the same techniques as in step 2.

Step 4: Metal Rectoscope with Endoscope. Dissection of Bovine Bowel Distended by Gas Insufflation

With this exercise close simulation of real operating conditions is achieved as operative work is only possible using the optics (Fig. 6.1 d). The most important aims are:

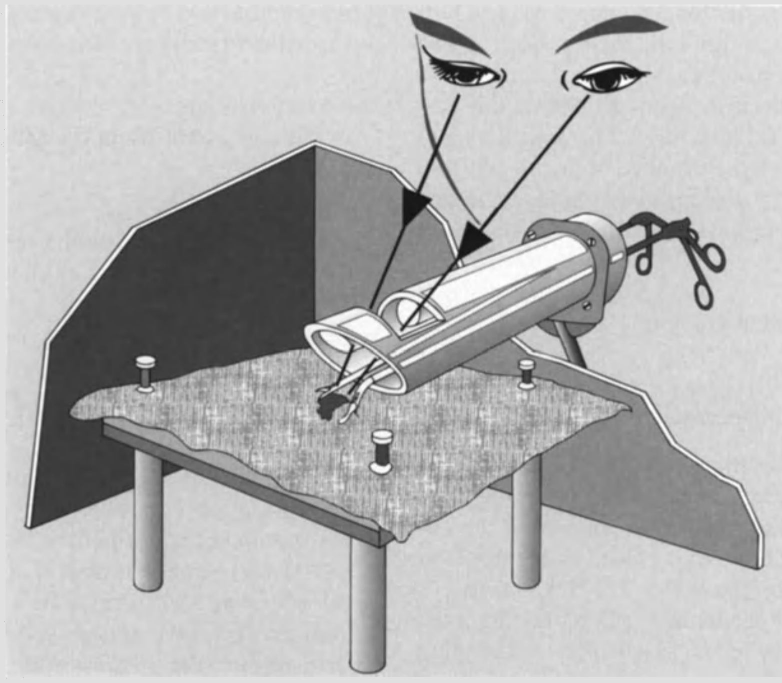
- The handling of the endosurgical combination unit for insufflation.
- The method of adjustment of the endoscopic optics and the rectoscope to result in maximal exposure of the operative field (Fig. 6.2). The distance of the front lens from the operative field may require adjustment for the various steps of the operation (Fig. 6.2 a, b).
- The use of diathermy.

Dissection Exercises
Full-thickness excision of the bowel wall results in gas leakage and collapsing of the lumen, resulting in loss of exposure. Therefore the phantom is altered to simulate the perirectal space in exercises where full-thickness excisions are performed. This is achieved by suturing a patch of bowel onto the resection area. When the inner bowel wall is excised, gas leakage is avoided. The following dissection exercises are performed.

Full-Thickness Excision. A 20-mm disc is excised and the defect closed by transverse continuous suture (Fig. 6.3 a) (see Chap. 24). Care must be taken that the suture incorporates a good bite of the muscular layer. In the clinical situation, this suture following extensive excisions is often under tension and mucosa alone is not strong enough to hold the suture.

Full-Thickness Excision in a Tumour Model. To simulate the presence of tumour, a piece of tissue is sutured to the mucosa, so creating a more realistic situation, i.e. the loss of view caused by polypoid structure (Fig. 6.3 b). The surgeon has to practise keeping a 5-mm margin of clearance during resection.

Mucosectomy. Mucosectomy (Fig. 6.3 c) is difficult using distended bovine bowel for two reasons. Compared to human bowel, the muscularis layer is thinner



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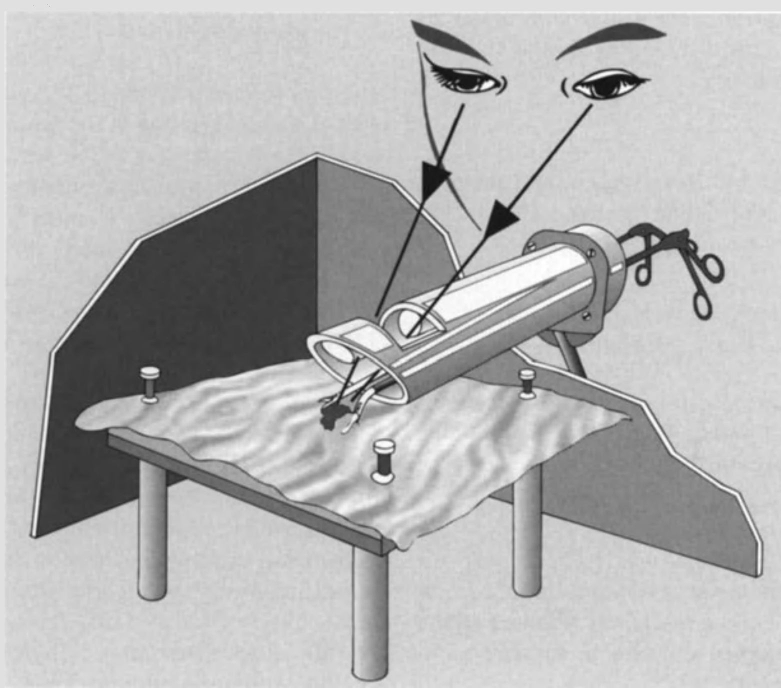
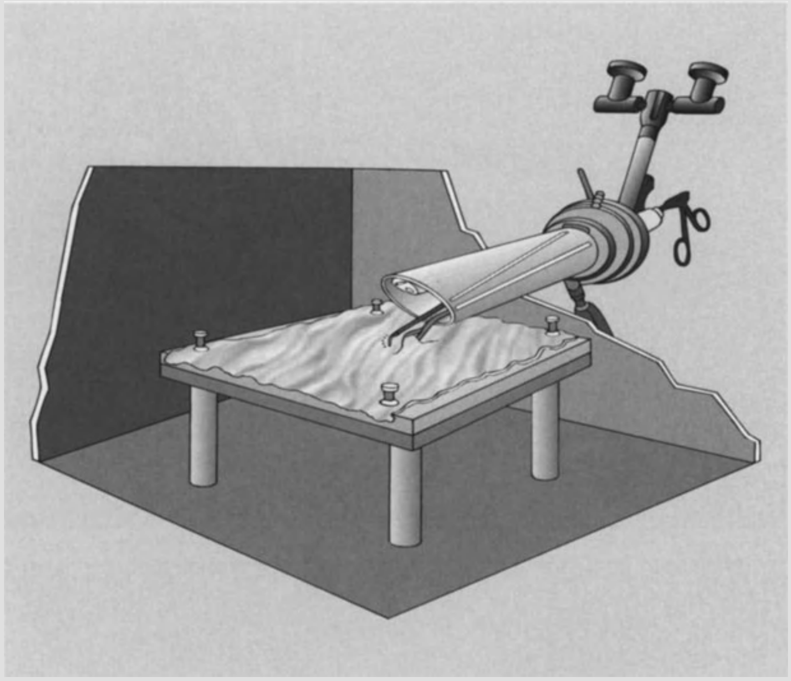


b

Fig. 6.1 a–d. The four steps of training for TEM. **a** Step 1: using direct viewing through the Plexiglas rectoscope, manipulation is performed on cloth. **b** Step 2: using direct viewing through the Plexiglas rectoscope, manipulation of opened bovine bowel is performed. **c** Step 3: rectoscopic dissection of opened bovine bowel with the metal rectoscope and stereoscopic optics. **d** Step 4: preparation in the closed bovine bowel with exposure provided by CO_2 insufflation



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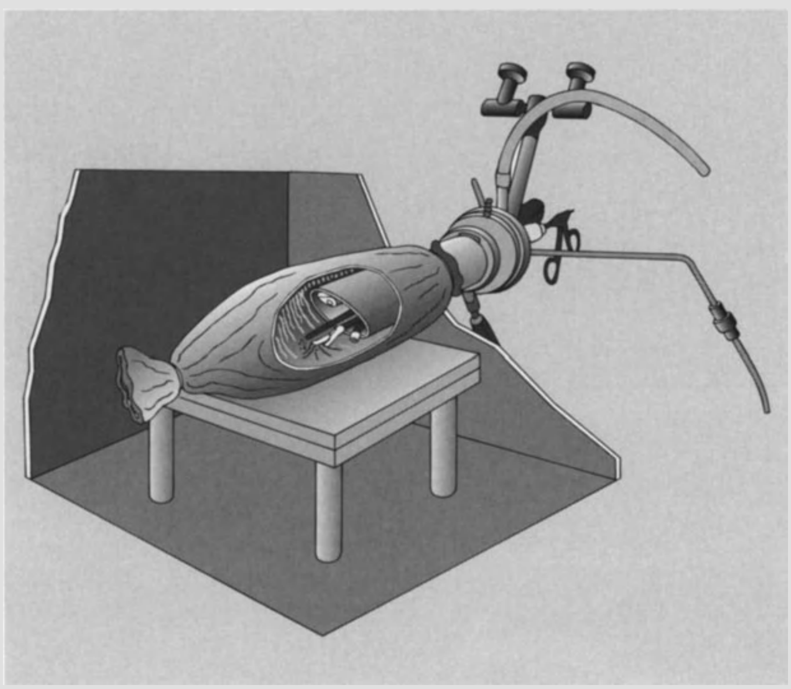

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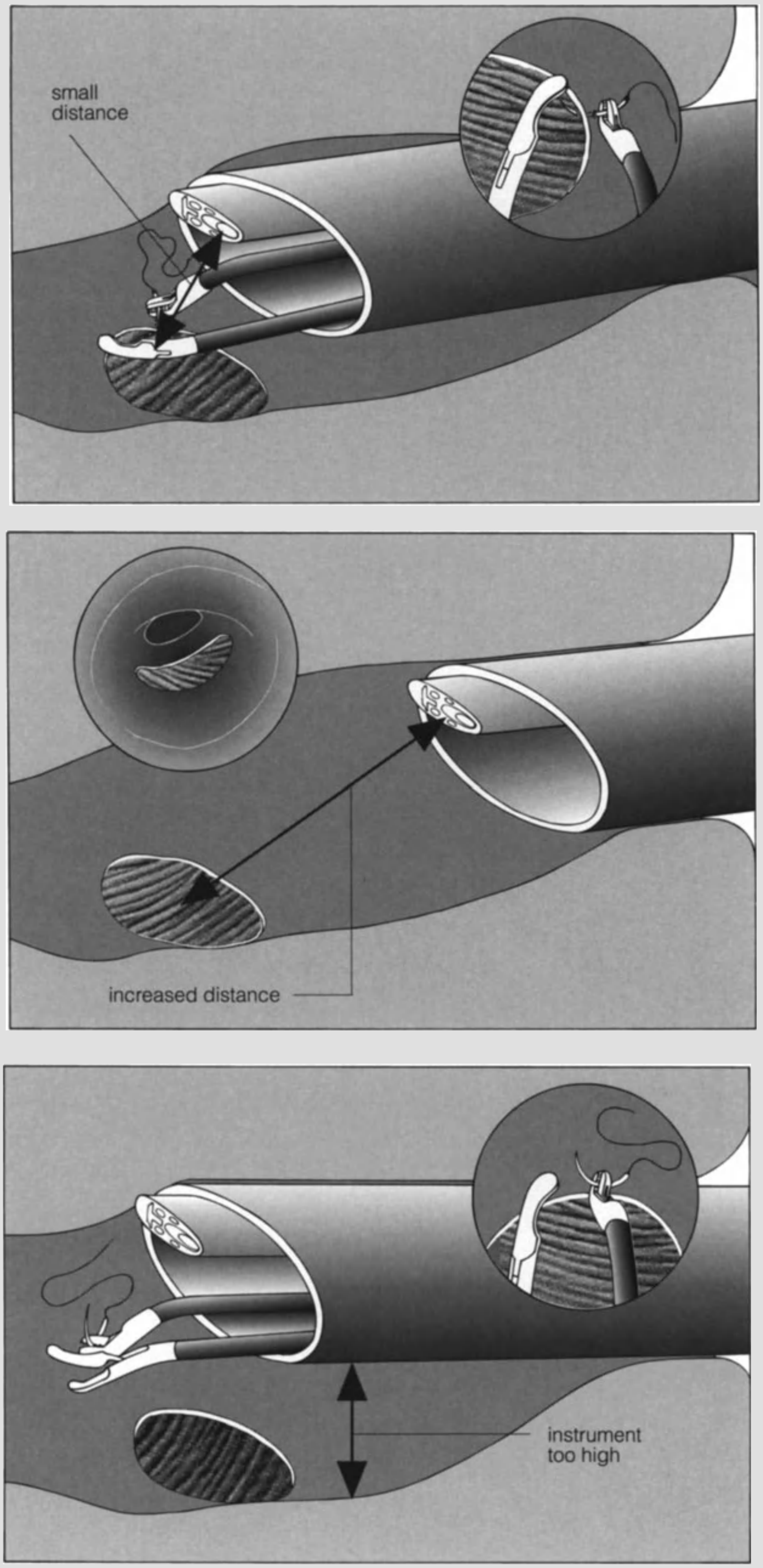

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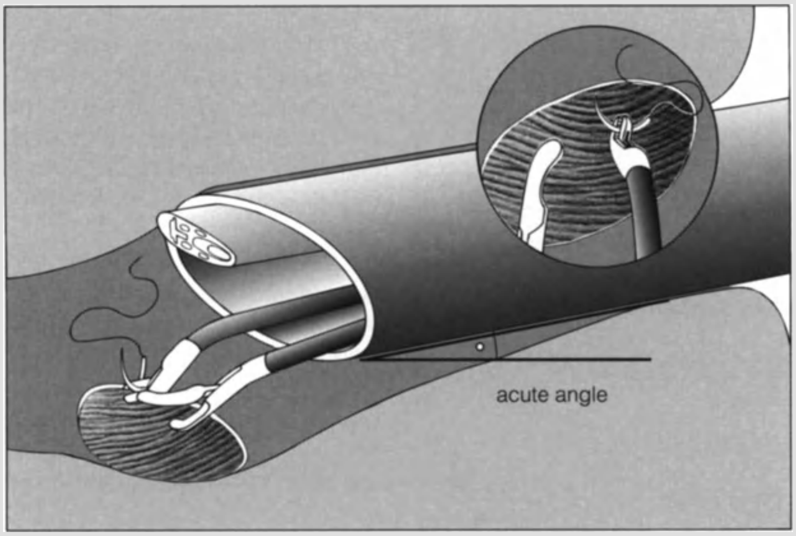

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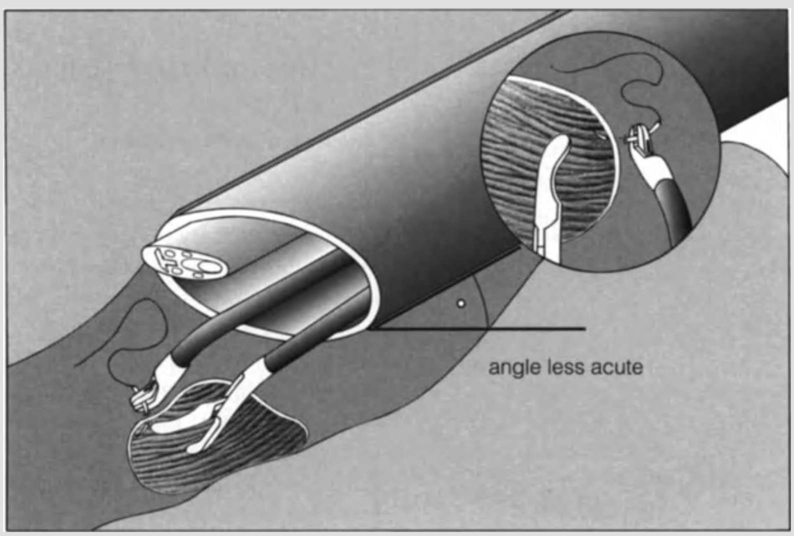
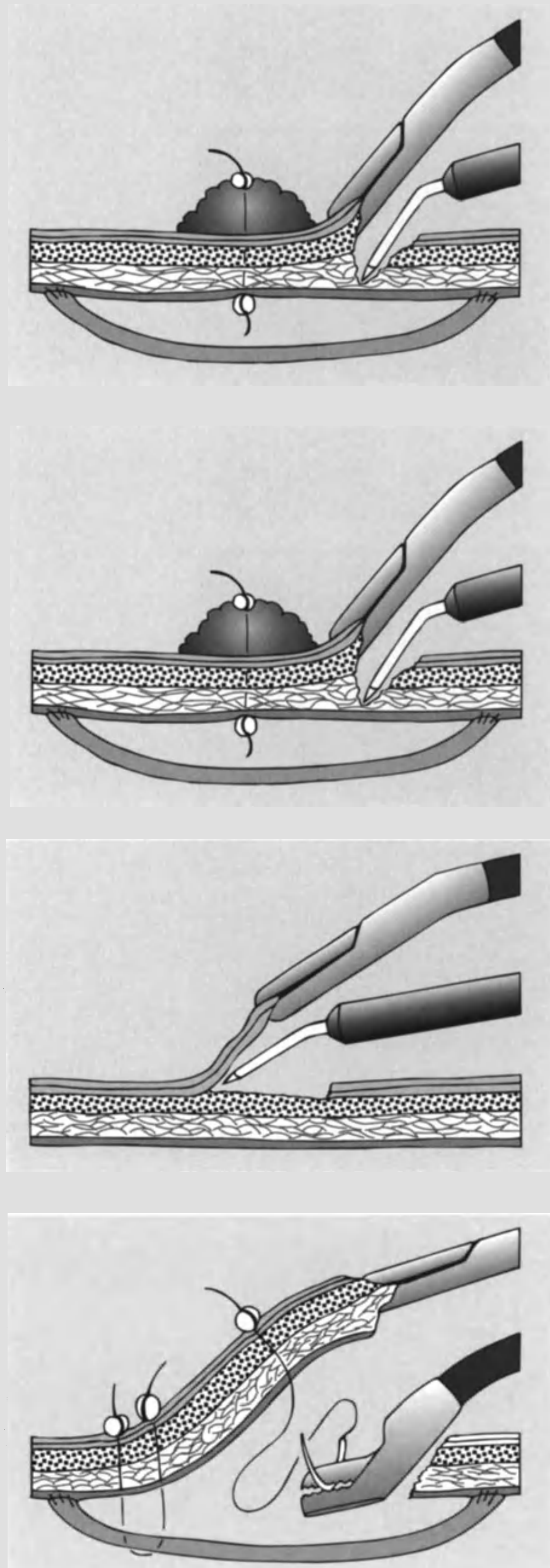


e

Fig. 6.2 a–e. Essential manoeuvres for positioning of the rectoscope. **a** Maximal amplification by close approximation of the object to the front lens. **b** Panoramic view by increasing the distance of the optic from the front lens. **c** Although good exposure of the operative area is achieved, the target tissue cannot be reached by the instruments. **d** If the angle is acute the direction of the instruments is too high. **e** Gaining instrumental access by increasing the angulation



a

b

c

d

and, because of lack of normal blood circulation, tissue layers are poorly defined. This is the reason the mucosectomy exercise is practised after the full-thickness exercise. Mucosectomy is performed on bowel without a patch. If dissection is too deep, gas leakage and loss of exposure result. Suturing incorporates full-thickness bowel wall as mucosal bites tear out.

Rectopexy. In preparation for this exercise, a piece of abdominal wall is sutured onto the bowel wall to simulate Waldeyer's fascia. Then a transverse full-thickness incision is made endoscopically near the tip of the rectoscope (Fig. 6.3 d). About 4 cm above this, two sutures are inserted following a "U" path. These sutures simulate fixation of rectum to Waldeyer's fascia. The incision is closed using the transverse continuous suture.

Training for Laparoscopic Operations

The Learning Programme

Laparoscopic procedures, typified by cholecystectomy, are developing rapidly to the point where they are becoming standard surgical procedures. A number of introductory courses are available so we only offer advanced courses. During these 5-day courses, the most important laparoscopic operations presently performed are taught: adhesiolysis, appendicectomy and cholecystectomy. The course covers the techniques and instruments for these procedures, but also provides other basic techniques of ES to cope with problems that might arise (step 1 of practical training).

Fig. 6.3 a–d. Operation exercises in step 4 of training. **a** A full-thickness excision is performed on bovine bowel modified by sewing on a bowel patch. **b** A simulated tumour is excised using the full-thickness technique on modified bovine bowel. **c** A mucosectomy is performed with unmodified bovine bowel. **d** Rectopexy is simulated on bovine bowel modified by a fascial patch

Steps of the Learning Programme

The introduction to the new techniques has to be gradual as for TEM. Theoretical knowledge and instrument handling are learnt in the first instance. The practical exercises comprise:

- Learning the functional mode of the endoscopic instruments
- Coordination of up to three instruments under direct view
- Performance of commonly used knotting and suturing techniques
- Handling of the endoscope under direct vision and after coupling it to a video camera
- The teamwork required (surgeon, assistant and cameraman)
- The handling of the suction/irrigation device and insufflation equipment
- The penetration of a porcine phantom abdominal wall using the Veress needle and establishment of a pneumoperitoneum
- Use of the monopolar and bipolar diathermy
- Adhesiolysis, appendicectomy and cholecystectomy in the phantom

Before starting simulation procedures of clinical operations, videos of the clinical operation are viewed. In the future it is planned to have video support of the course with video tapes designed specifically to demonstrate each step of the procedure.

The acquisition of practical skills in the course progresses in gradual steps. The first two steps are performed by viewing without the endoscope and then by direct vision down the endoscope. Participants share a phantom and mutually assist each other. From the third step the video system is used, and the surgeons operate in teams of three.

Practical Exercises on the Semm Pelvitrainer

Step 1: Knot Tying and Suturing Techniques

The Semm Pelvitrainer has a transparent Plexiglas roof with ports for the endoscopic instruments (Fig. 6.4). Three different viewing conditions are possible similarly as in TEM. Figure 6.5 shows the three levels of optical control: direct viewing, endoscopic and direct viewing, and endoscopically with covered Plexiglas. With the covered phantom the video camera is necessary to provide a view for the assistants. During this phase of the course, knot-tying and suturing techniques are performed on cloth and animal tissue:

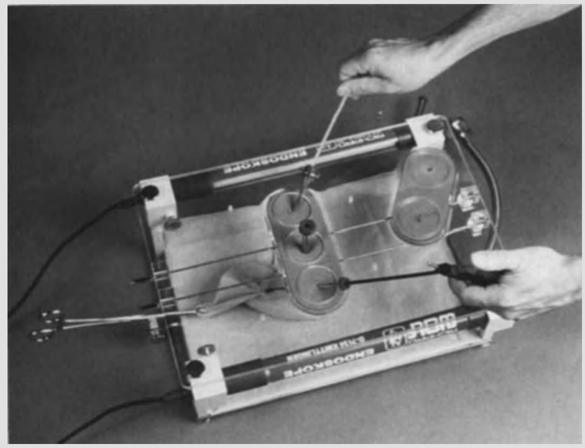
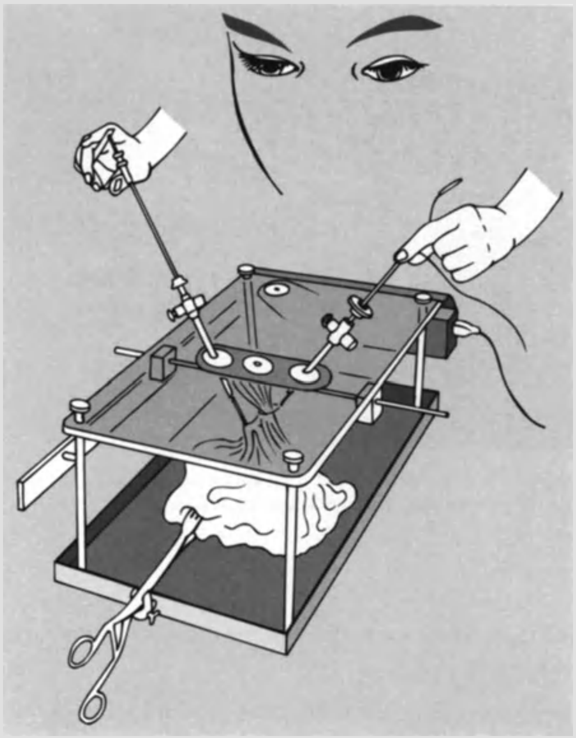


Fig. 6.4. Semm's Pelvitrainer with Plexiglas roof through which instruments and the endoscope can be introduced

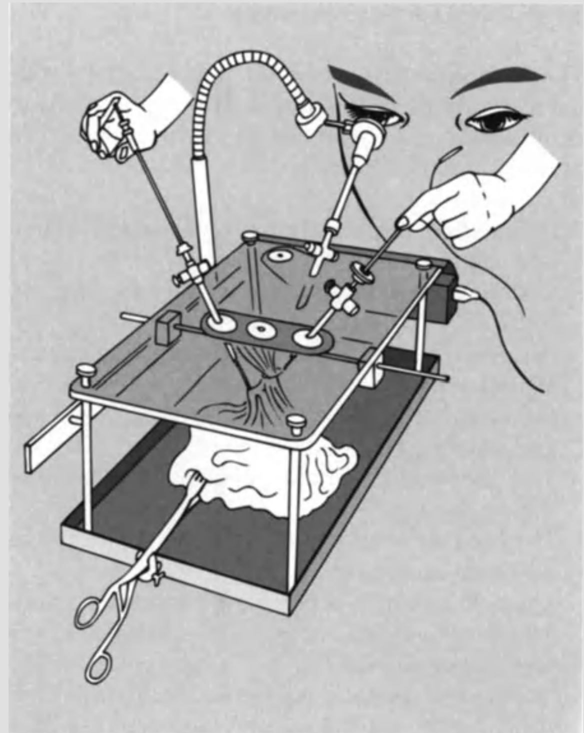
- Ligation using the pretied catgut Ethibinder or Surgitie
- Ligation after insertion of suture around a pedicle using the extracorporal Roeder and other knots
- Interrupted and continuous suturing techniques with extracorporeal and intracorporeal knots (see Chap. 7)
- Stapled anastomoses

Step 2: Trocar Insertion

Step 2 of training includes the simulation of Veress needle placement and trocar insertion on the modified Pelvitrainer (Fig. 6.6). Complications in laparoscopic surgery are most often associated with trocar insertion, and so care is taken to practise them on the Pelvitrainer. Furthermore, this practice is repeated using the porcine abdominal wall. This includes the reusable trocars and the disposable ones marketed by AutoSuture and Ethicon.



6.5 a



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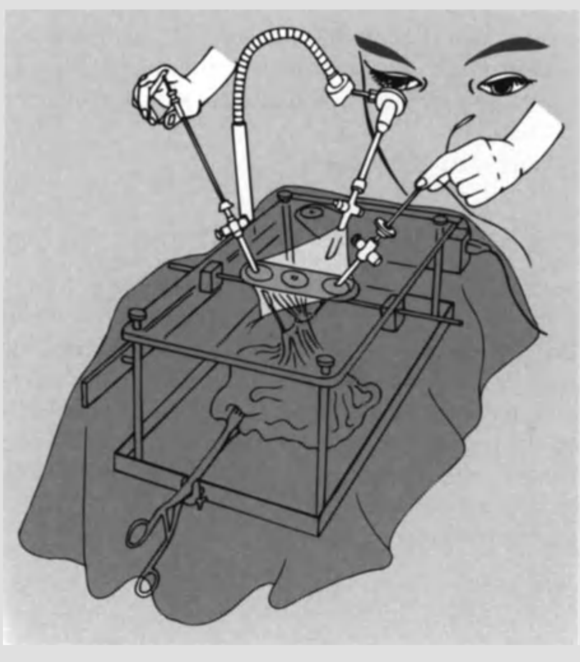

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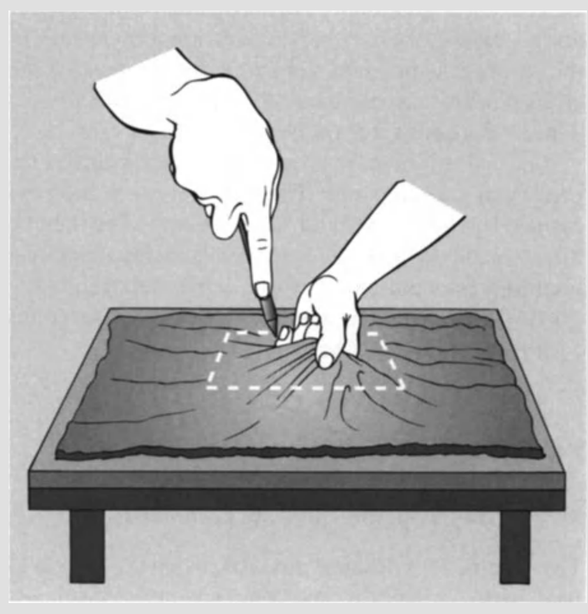
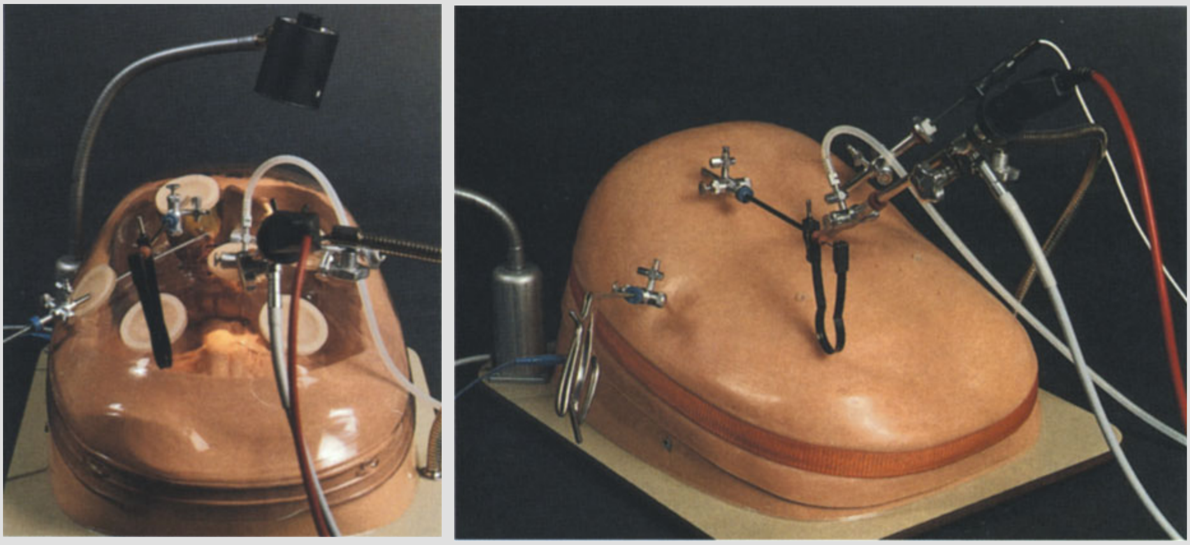


6.6

Fig. 6.5 a–c. Semm's Pelvitrainer can be used with three levels of optical control: **a** direct viewing; **b** endoscopic viewing complemented by direct viewing; **c** endoscopic viewing alone after covering the Plexiglas

Fig. 6.6. Semm's Pelvitrainer is modified by using a Plexiglas roof with a bigger entrance. Through this entrance various techniques of puncture are performed on porcine abdominal wall



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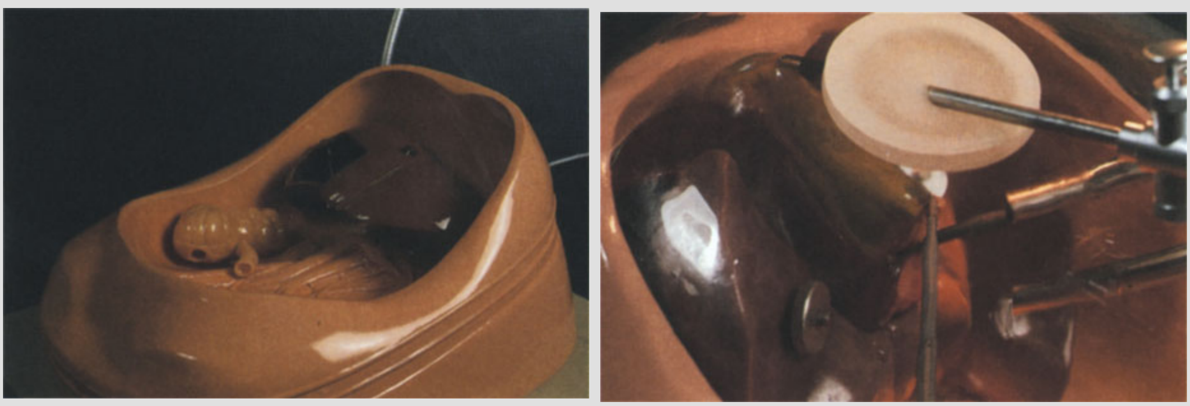


6.8a b

Fig. 6.7 a, b. Design of the Tübingen Trainer: **a** transparent roof with integrated ports for the instruments; **b** elastic roof

Fig. 6.8 a, b. Tübingen Trainer for operative laparoscopy. **a** Trainer with plastic organs. **b** A segment of porcine liver with attached gallbladder is inserted into the receptive fossa of a plastic liver

Dissection Using the Closed Anatomical Phantom (Tübingen Trainer)

Structure of the Phantom

The phantoms presently available do not provide optimal training for general surgery. We have developed new phantoms which are used in the course of operative laparscopy. (Tübingen Trainer designed by Naruhn, Buess and Moetzung). These phantoms are based on anatomical torsos made by the Coburger Lehrmittel Anstalt (CLA; 8630 Coburg, Germany). The construction allows incorporation of either an "abdominal wall" of Plexiglas (Fig. 6.7 a) or a flexible rubber wall as a substitute for the abdominal wall (Fig. 6.7 b). By this method, accurate simulation of trocar insertion through the abdominal wall is possible. Animal organs and tissues required for the exercises can be placed in the "abdominal" cavity (Fig. 6.8).

Fig. 6.9. Position of the operating team for appendicectomy and adhesiolysis. The surgeon stands to the left caudad to the cameraman

Operation Teams and Video Technique

From step 3 onwards participants work in teams of three, as in clinical procedures. Using a video camera attached to the endoscope, all steps of the procedures are carried out operating from the video screen. This procedure has certain advantages:

- The operating team and theatre staff can all follow the progress of the operation on the video screen.
- Usual teamwork is possible in contrast to operation by direct vision through the endoscope.
- Avoidance of contact between the endoscope and the surgeon's face maintains the sterile field.
- The surgeon can work in a comfortable body position in contrast to stooping over to maintain direct vision through the endoscope.

The surgeon carries out the dissection. The cameraman comes next in importance by guiding the endoscope with the attached camera, providing optimal overview or close-up details as required. Jerky movements of the camera hinders precise surgical work. Alternatively, the use of easily adjustable laparoscope holders can be demonstrated and practised.

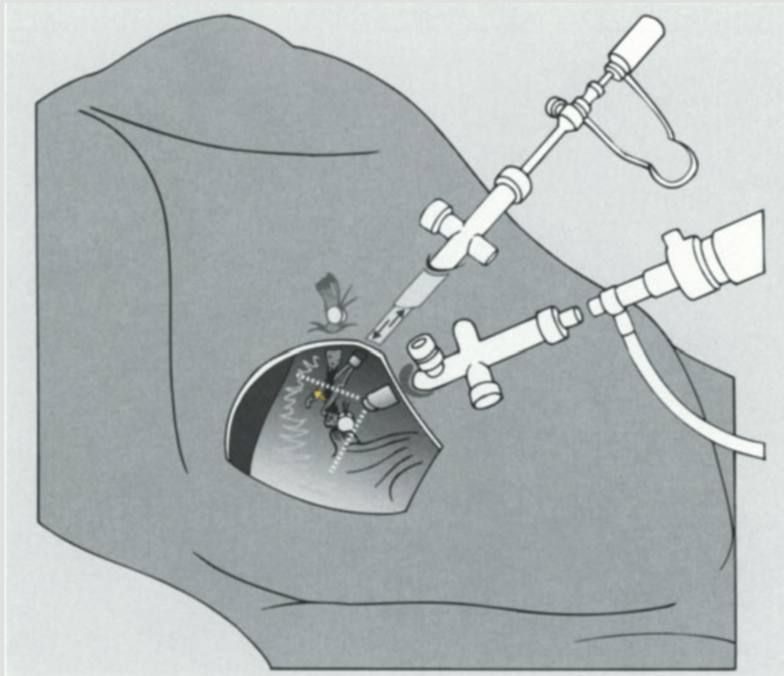
Early in training the assistant has only to maintain the constant instrument position; the surgeon places them in. With experience the assistant participates in the dissection by actively exposing the optimal tissue plane for the surgeon. During the course each participant rotates through the various roles of surgeon, cameraman and assistant.

Step 3: Adhesiolysis

Division of adhesions is one of the most important endoscopic operations. In contrast to open surgery, the exposure is better and the wounds created are less likely to cause subsequent new adhesions. Using the Tübingen Trainer, an adhesion is created in the right iliac fossa between an animal bowel and the anterior abdominal wall using a strip of its mesentery. The operation is performed using the same team position as for appendicectomy (Fig. 6.9). The adhesion is divided in the following ways (Fig. 6.10 a):

- Bipolar coagulation close to the abdominal wall followed by cutting using hook scissors (Fig. 6.10 b)
- Scissor division followed by Ethibinder or Surgitie ligation of the stump on the mesenteric aspect (Fig. 6.10 c)
- Preliminary ligation in continuity using Roeder knots tied extracorporeally (Fig. 6.10 d)

Fig. 6.10 a–d. Adhesiolysis using the Tübingen Trainer. **a** A strip of the mesentery is attached to the roof, simulating an adhesion and bipolar coagulation (*yellow arrow*) is applied; **b** cutting after bipolar coagulation; **c** cutting with scissors and subsequent ligation of the stump close to the bowel; **d** double ligature in continuity using Roeder knots



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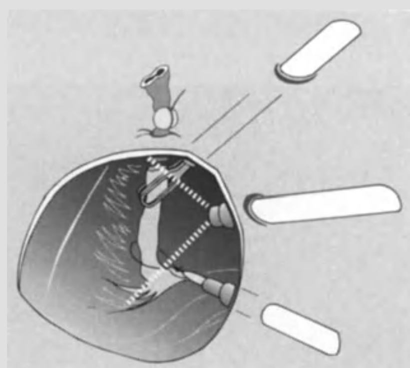

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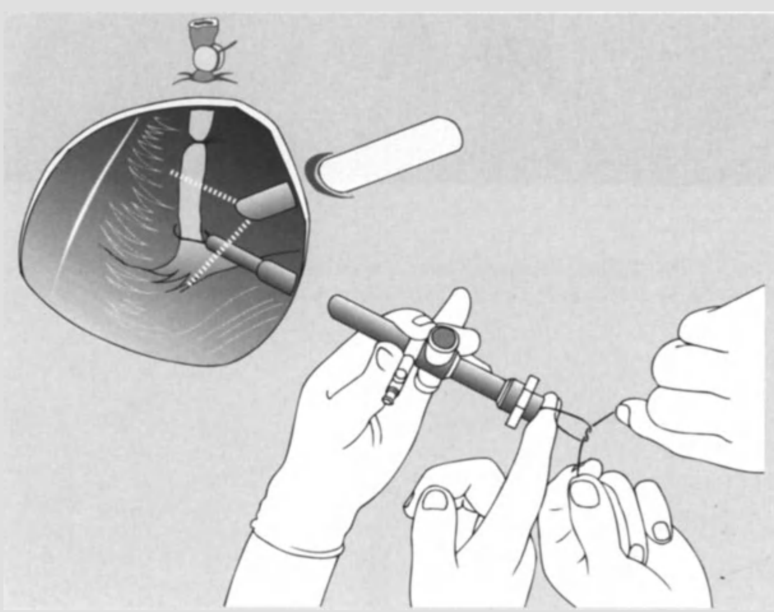

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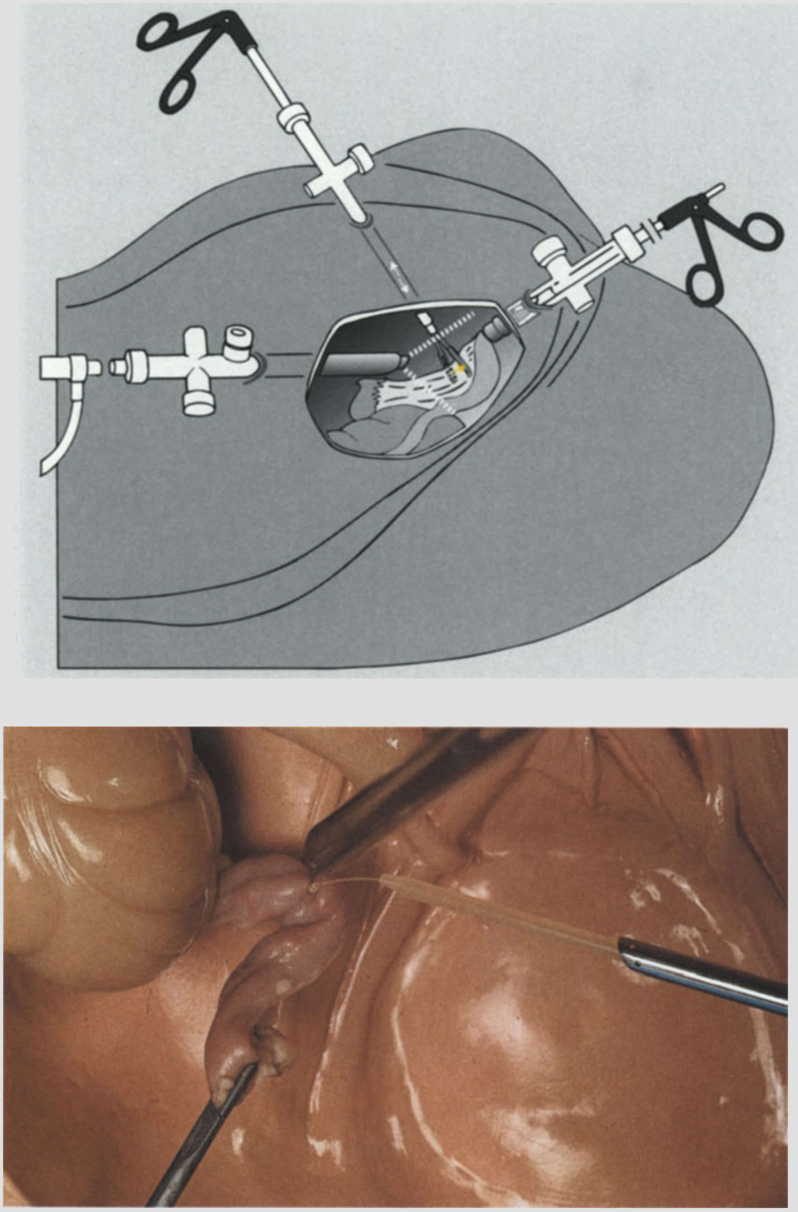


a

b

Fig. 6.11. **a** Appendicectomy with the Tübingen Trainer. A loop of small bowel simulating the appendix is inserted inside the plastic colon. The mesoappendix is coagulated by bipolar forceps. **b** Ligature of the appendix

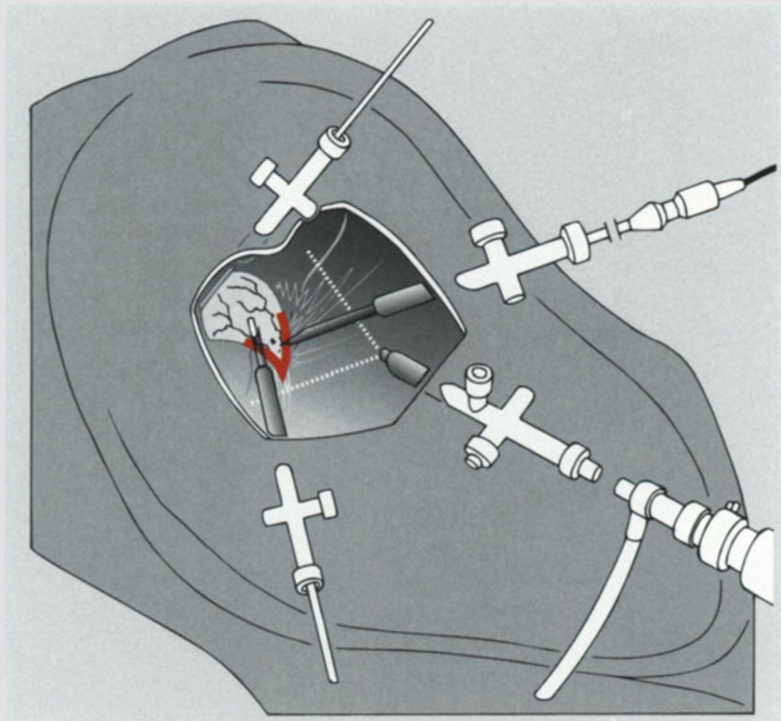


Fig. 6.12. Cholecystectomy with the Tübingen Trainer. A segment of porcine liver with attached gallbladder is fitted into a preformed space of a plastic liver. The gallbladder is held by two grasping forceps. V-shaped dissection of the neck

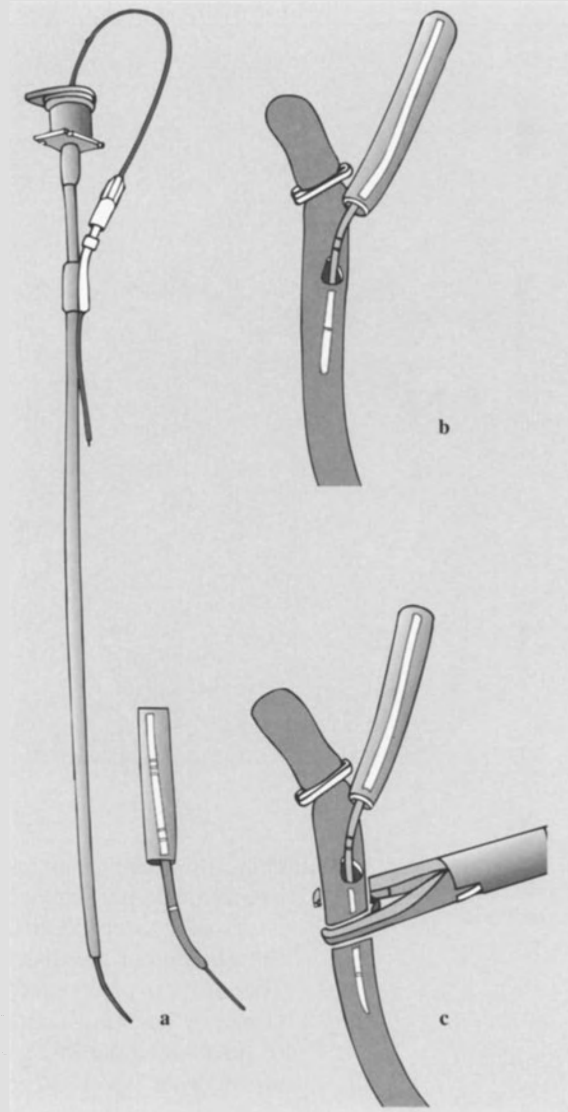
Step 4: Appendicectomy

This operation incorporates further surgical techniques. We teach the technique as described by Goetz: the phantom is prepared by mimicking the appendix with small bowel introduced into the caecum (Fig. 6.11). The small bowel mesentery mimics the mesoappendix. This is coagulated using bipolar forceps before scissor division. The appendix stump is ligated using an Ethibinder (Fig. 6.11 b; see Chap. 15).

Step 5: Cholecystectomy

Extensive training covering all steps of cholecystectomy is the main aim of the course. We teach the standard procedure based on preliminary dissection of the cystic pedicle. A porcine liver segment with attached gallbladder is fitted into a preformed space of a plastic liver (Fig. 6.12). Closely following the steps performed clinically, each participant performs four cholecystectomies and so participates in 16 operations.

As a first step Hartmann's pauch and the neck of the gallbladder are dissected in a V-shaped manner. Thereafter the cystic duct is dissected. Exposure is obtained by upward traction on the fundus of the gallbladder, using the forceps inserted subcostally in the line between navel and gallbladder. The lateral grasping forceps via the port at the anterior axillary line is used to manipulate Hartmann's pouch (Fig. 6.12). Close to the gallbladder, the connective tissue which covers the cystic duct is removed using the monopolar hook dissector (see Chap. 16). Only small amounts of tissue are lifted up with the hook before cutting to prevent coagulation injury to the adjacent tissue. The cystic duct is encircled using the hook and freed over a distance of 2 cm. The small porcine cystic duct is clipped close to the gallbladder, opened with microscissors and cannulated with a ureteric catheter with a bent tip. (Rüsch, 7050 Waiblingen, Germany). This is introduced through the centre of a suction probe (Fig. 6.13 a) and held in position by a partially closed clip (Fig. 6.13 b). By advancing the ureteric catheter, the suction probe is withdrawn 5 cm to keep it from the area of interest during the simulated cholangiogram. The completion of the dissection follows the steps outlined in Chap. 16.



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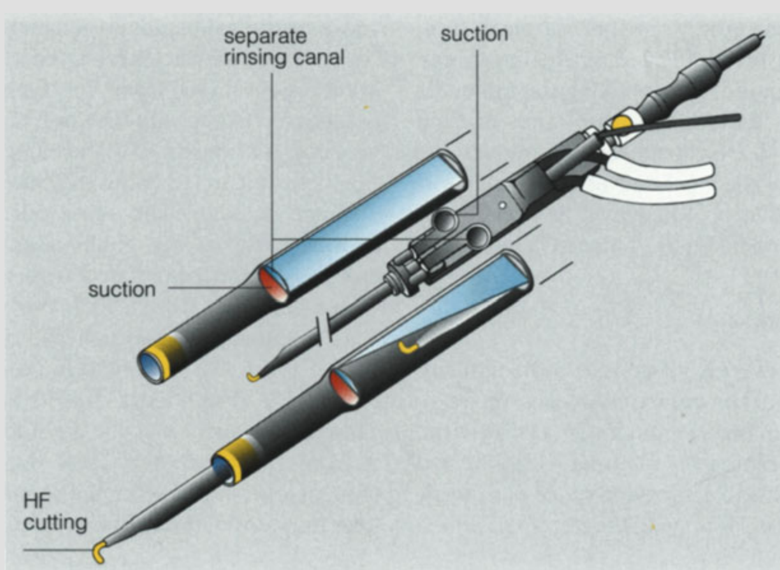

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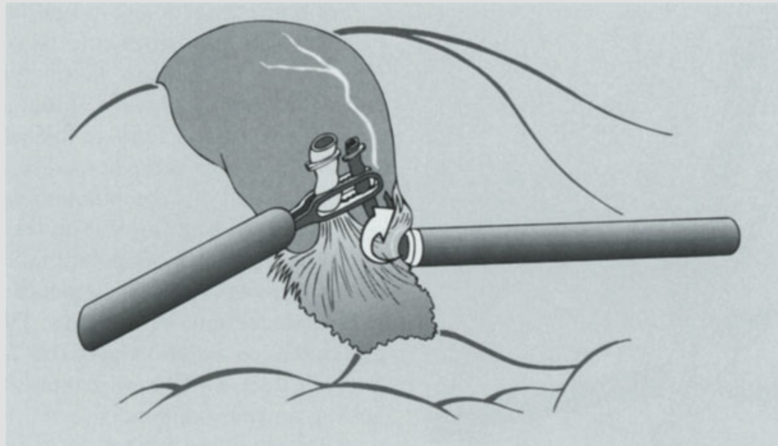

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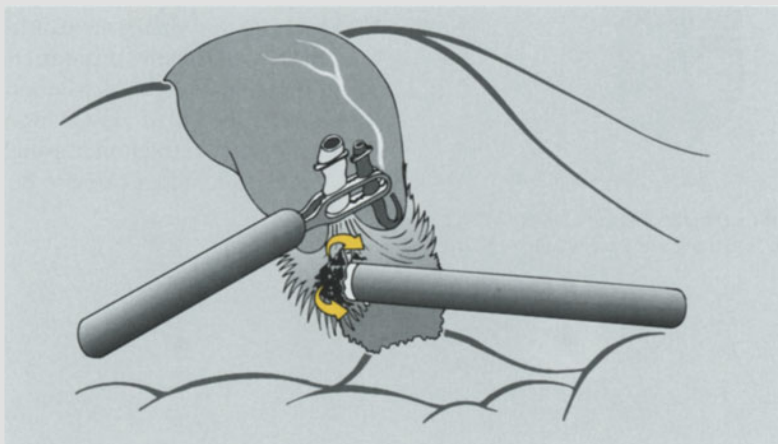

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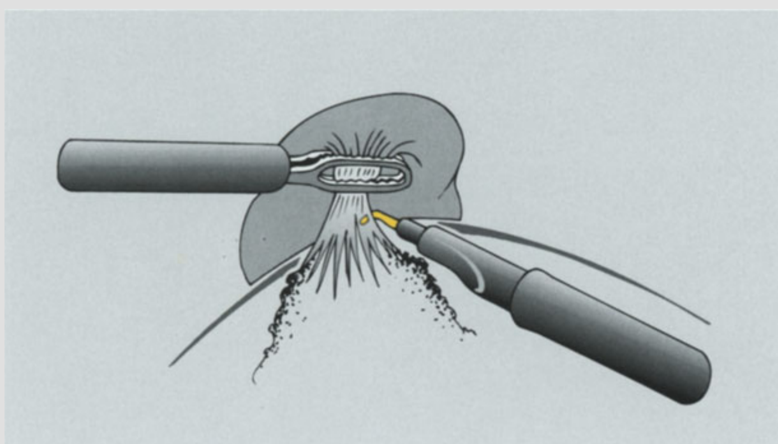


d

Fig. 6.13a–c. Exercises for intraoperative cholangiography. **a** Catheter for cholangiography. 7050 Waiblingen, Rüsch, Germany. **b** A modified ureteric catheter with a preformed angle is introduced into the cystic duct. **c** The catheter is held in place by a partially closed clip across the cystic duct

Fig. 6.14a–d. Dissection with the combination sucker. (Wolf, 7134 Knittlingen, Germany). **a** Combination instrument. **b** The gallbladder is bluntly dissected with the specially designed sucker tip. **c** Bleeding vessels are coagulated with the tip of the combination instrument (*yellow arrows*) **d** Electrical cutting with the hook

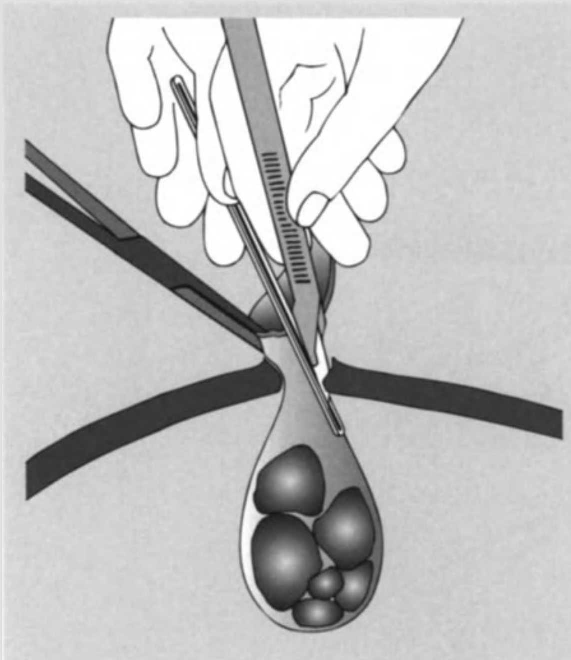


Fig. 6.15. Extraction of the gallbladder via the navel. With large stones the navel incision is enlarged using a small metal guard

For blunt dissection of the gallbladder from the liver we use a new instrument, the combination sucker (Wolf, 7134 Knittlingen, Germany). This has a special tip design, allowing blunt tissue separation (Fig. 6.14 a), similar to swab dissection. Five-millimetre instruments (e. g. the hook dissector) can be inserted centrally. In this combination we use the hook for coagulation and cutting of exposed vessels (Fig. 6.14 b) In our experience monopolar diathermy is safe to use in situations where no thin structures are involved, e. g. liver bed, rectum, oesophagus. Particular care with monopolar coagulation has to be taken near the common bile duct as well as with thin structures such as adhesions and mesoappendix.

After complete dissection of the gallbladder, the endoscope is moved to the left upper port and the gallbladder extracted via the navel incision (Fig. 6.15). Extension of this incision, if required, is easily achieved using a small metal guard. Methods of dealing with a large gallstone load involving extractors, stone lithotripsy and extraction through the exteriorized neck of the gallbladder can also be demonstrated and practised.

7 Basic Surgical Procedures

A. Cuschieri, L. K. Nathanson, and G. Buess

Introduction

Dissection, haemostasis, knotting and tissue approximation constitute the essence of surgical practice whether this is open or laparoscopic. With the present technology there are a number of restrictions which impose an extra degree of difficulty in executing these basic surgical skills by the laparoscopic approach. An appreciation of the nature of these problems helps the surgeon to modify or adapt the technique to enable the necessary level of proficiency and speed to be achieved. The important restrictions include problems with depth perception and instrument coordination, interpretation of the endoscopic anatomy which is often magnified by the optic to a varying extent depending on the distance between the end of the telescope and the target field, and restricted instrument mobility imposed by the attachment of the access cannulae to the abdominal wall or the limited internal diameter of the operating endoscope (mediastinoscope or rectoscope). These problems are reviewed in detail in Chap. 13.

Dissection

Exposure, Manipulation and Retraction

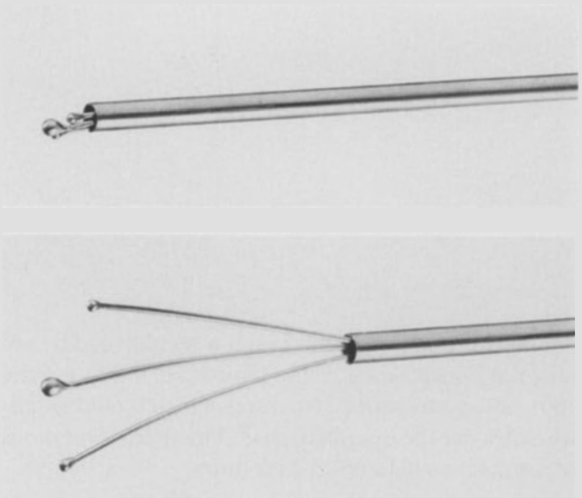
Dissection of tissue planes is dependent on adequate exposure of the relevant anatomy. As in conventional open surgery, tissue planes are revealed by traction and countertraction using atraumatic graspers. Correct siting of the trocar and cannulae is crucial to achieve this with ease. Careful stepwise lifting of tissue using two atraumatic graspers forms the basis of manipulation. The tissue (e. g. small bowel) is grasped by the left forceps and held tented until it is picked up further proximally or distally (as required) by the right grasper when the left hold is released and the left forceps applied further down, and so on. The process resembles "walking on stilts".

Exposure of a particular region is enhanced by appropriate positioning of the patient such that gravity shifts away unwanted structures which would otherwise obscure the operative field. The specific methods of retraction available are as follows.

Grasp-Lift Traction. This method is applied on tissues or hollow viscera using 5.0-mm graspers. It is preferable that these are of the atraumatic variety and have a self-locking mechanism. Especially if prolonged tension is kept on the structure, the use of traumatic forceps may lead to perforation of the organs with leakage of contents particularly when the grasper is removed. If the same position is required for some time, the grasper can be clipped in the desired position to the drapes or preferably held in an adjustable clamp fixed to the rail of the operating table.

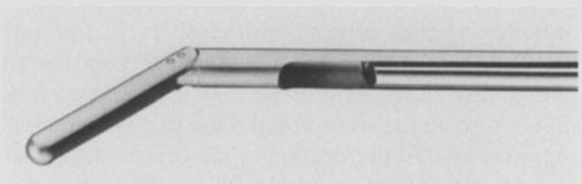
Elevation-Rod Retractors. These are inserted under solid organs such as the left lobe of the liver and by depression of the external part are used to lift the structure to expose the underlying anatomy to the optic. The most commonly used rod retractor is the 5.0-mm palpating probe. Care is needed in the use of such a device to avoid stabbing of the hepatic parenchyma, which can occur despite the rounded end of the instrument. Another hazard follows from the use of excessive pressure by the rod which may lead to splitting as the rod indents the liver substance. In this respect the use of the fan or umbrella retractor (Fig. 7.1) minimizes some of these problems and provides lift of the liver over a wider surface.

Endoretractor. This instrument (Fig. 7.2) has two distinct advantages. The first is that it does not use up one of the available accessory operating cannulae since it is introduced through the 11.0-mm optical cannula over the telescope. The second advantage stems from the fact that the retractor moves with the optic and lifts structures ahead of the visual field. It has three segments: a thin long cylinder which fits over the optic and inside the cannula beyond which it projects externally, a half-circle 5.0-cm viewing section (open inferiorly)



7.1 a

b



7.2

Fig. 7.1 a, b. Three-pronged (5-mm) retractor. When the bulbous prongs are extruded, lift over a wider surface is provided (Storz): **a** Closed; **b** open

Fig. 7.2. Components of the endoretractor: the retracting rod which drops down in front of the optic, the viewing section which consists of a half-circle segment open inferiorly and the long cylindrical section into which the 30° 10-mm telescope is introduced (Storz). Retractor with 30° forward-oblique telescope inside

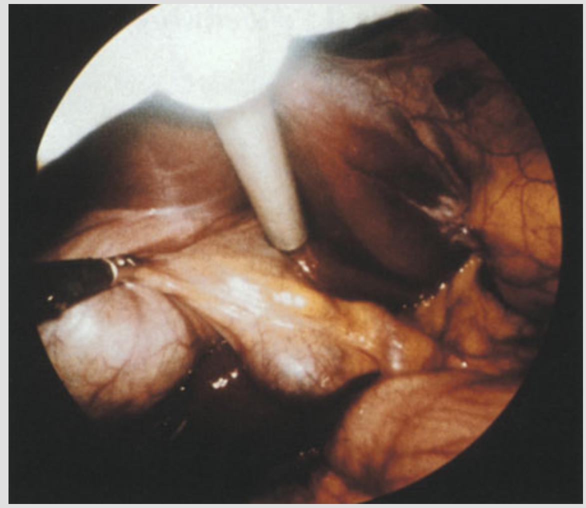


Fig. 7.3. Endoretractor in use during laparoscopic cholecystectomy

through which the end of the 30° 8.0-mm optic can be moved, and a terminal retractor end which consists of a rod. This drops down following insertion to an angle of 45° with the horizontal. Adjustments to the retraction requirements are easily achieved by telescoping the cylinder over the optic or vice versa. We have found the use of this prototype instrument particularly useful in subhepatic surgery, e.g. cholecystectomy, vagotomy and mobilization of the gastro-oesophageal junction (Fig. 7.3).

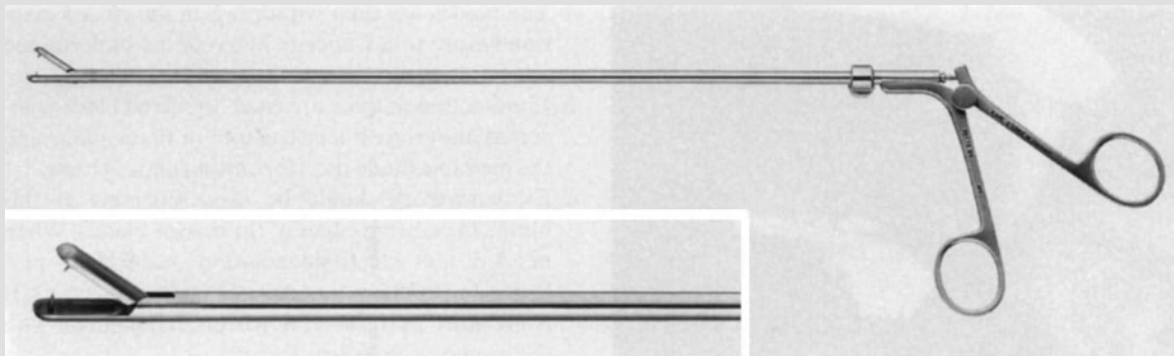
Technique and Types of Dissection

Certain general principles apply irrespective of the type of dissection practised: gentle handling of the tissue, precise grasping and care to avoid oozing which obscures the visual field to a greater extent than in open surgery as the dark red blood obscures vision by absorbing the incident light from the optic.

Whenever possible, a two-handed dissection should be used whereby the surgeon lifts the tissue with an atraumatic forceps using the left hand and dissects with the desired instruments using the right hand. Two-handed dissection is considerably facilitated by the use of laparoscope holders (see Chap. 13) which, by obviating the services of a cameraman, create more elbow room in the immediate vicinity of the operating table.

Blunt Dissection

The technique of pledget swab dissection developed in Dundee is an important ancillary method to other forms of dissection. The required instruments are 5.0-mm spoon biopsy forceps (Fig. 7.4) and an appendix extractor. The technique can only be used with safety with a metal 11.0-mm cannula. The disposable cannulae are unsuitable for this purpose as the flap valve catches the pledget swab during withdrawal with a real risk of dislodgement. During assembly, the scrub nurse first introduces the spoon biopsy forceps inside the appendix extractor (Fig. 7.5). The swab is then impaled on the sharp prong fixed to the inside of the lower cusp before the instrument is closed on the swab, the anterior part of which projects beyond the end of the instrument. The latter is kept forcibly closed by winding sterile rubber bands around the handles of the instrument. The tip of the biopsy forceps holding the pledget swab is withdrawn inside the appendix extrac-



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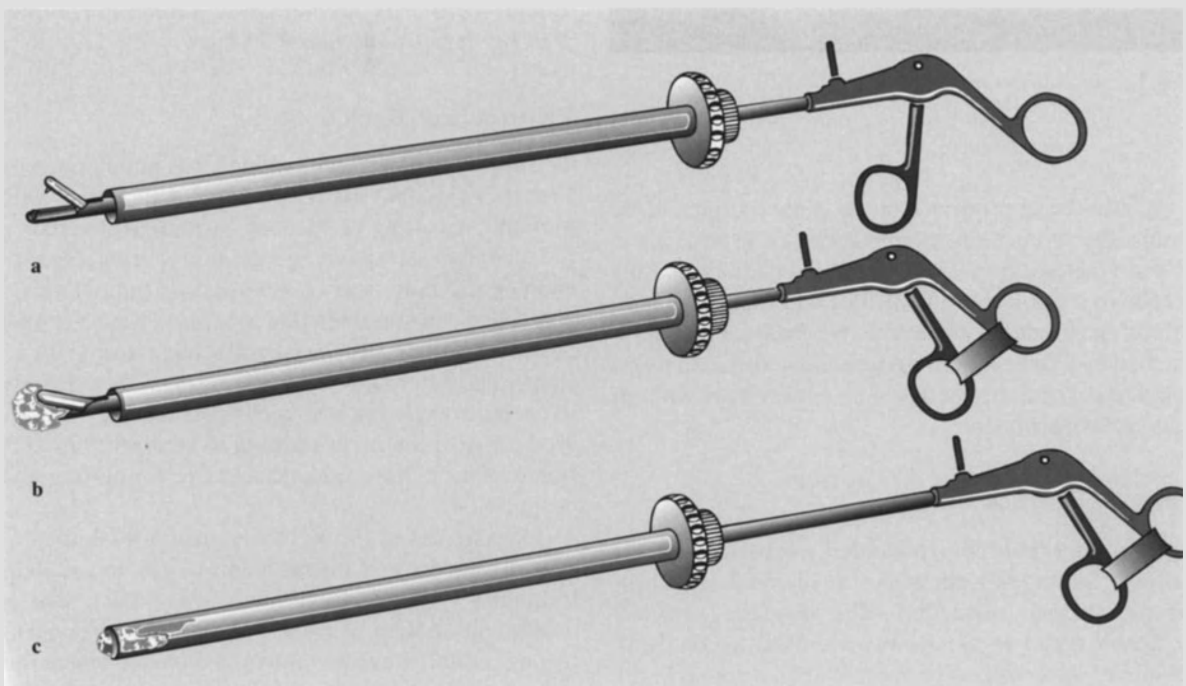


7.5

Fig. 7.4. Spoon biopsy forceps for grasping pledget swab (Storz)

Fig. 7.5 a–c. Assembly used for pledget swab dissection. **a** The spoon biopsy forceps is first introduced through the appendix extractor. **b** The jaws are used to grasp the pledget, and rubber bands are applied on the handles to keep the jaws firmly closed. **c** The biopsy forceps grasping the swab is then retracted inside the appendix extractor before the assembly is handed to the surgeon

tor before it is handed to the surgeon. It is inserted in this position inside the 11.0-mm cannula to the operative field.

Pledget swab dissection is particularly useful for opening up tissue planes, separation of loosely bound structures such as the gallbladder from the liver bed, mobilization of hollow organs, e.g. gastro-oesophageal junction, separation and clearing of delicate structures, e.g. arteries, ducts and nerves, and in mopping up or controlling minor oozing (Fig. 7.6). On completion of the swab dissection, the end of the forceps including the pledget swab is retracted inside the appendix extractor before withdrawal through the 11.0-mm cannula.

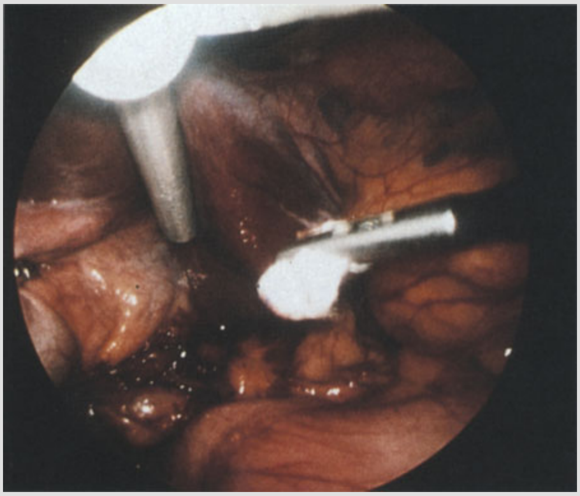


Fig. 7.6. Swab dissection in use

Once the appropriate tissue plane is opened by sharp dissection, blunt mobilization can be achieved in some situations by use of the closed scissors, palpating probe or suction instrument. The latter is particularly useful in situations where the mobilization is accompanied by a constant minor ooze as the field can be aspirated dry and irrigated whenever necessary without change of instrument.

Scissors Dissection

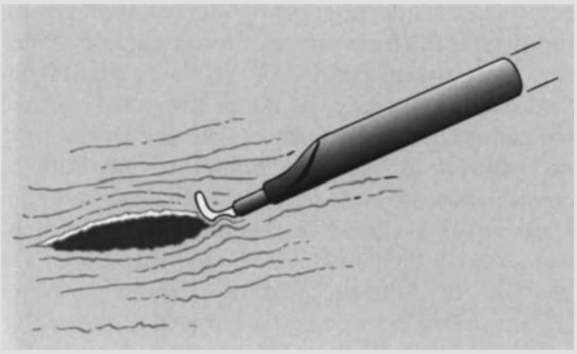
We consider that the two-handed scissors-atraumatic forceps technique is the mainstay of complex laparoscopic surgical dissection. The dissecting scissors available are of two kinds: twin- and uni-action. Both blades of the former type are movable, whereas in the uni-action variety one of the blades is fixed. The twin-action instrument is preferable because teasing of tissue to create the necessary plane by opening the blades is evenly distributed on both sides and therefore less likely to cause tearing by unequal shear. The ideal dissecting scissors should be insulated right up to the blades and be slightly curved at the tip. There are certain guidelines for the safe use of scissors during dissection:

1. The instrument is advanced under vision in the closed position until it reaches its target.
2. A small superficial incision is made in the peritoneal lining of the structure to be mobilized.
3. The blades are introduced in the closed position inside the created defect and then gently opened to create the plane.
4. The blades are then withdrawn in the closed position before re-advancement to cut the undermined edge or structure.
5. If uni-action scissors are used, the fixed blade is inserted underneath the structure or tissue plane and the movable blade used for cutting under vision.
6. Electrocautery should be used sparingly as this blunts the cutting edges of the scissor blades. When needed, soft electrocoagulation (<200 V) is performed with the outer edge of the closed scissors. It is far more preferable, however, to coagulate with the insulated dissecting forceps.
7. When not in use, dissecting scissors should be withdrawn completely or inside the accessory cannula, since the sharp ends may cause stab wound injuries to any organ, particularly the liver.

Electrosurgical Hook Knife

This is a useful instrument which was popularized by French surgeons. It is used in association with monopolar cutting or blender current. To overcome the problem of smoke generation during electrocautery, the hollow instrument has a trumpet valve-controlled suction/irrigation system. There are two basic functional ends: the curved semicircle and the L-shape. The latter allows better control and is less likely to become tangled or adherent to the tissues. The Valley-Lab instrument, in addition to incorporating suction/irrigation, has exchangeable tips for cutting and coagulation.

The safe use of the electrosurgical hook knife entails an awareness of the mechanism of action of high-frequency (HF) electrocutting (monopolar). This is dependent on the production of electric arcs concentrating the entire current onto a single point where the tissue is immediately vaporized. The operating peak voltage to produce this effect has to be in the 200–500-V range. If the voltage drops below 200 V, tissue cutting cannot be achieved since the electric arcs cannot be generated. On the other hand, if the voltage rises above 500 V, the electric arcs produced are so intense that the tissue is carbonized and the electrode may be damaged. Within the safe operating range, the depth of the coagulation of the cut edges increases with increasing voltage and intensity of the electric arcs. In practice, the depth of coagulation during electrocutting is determined by the setting of the HF output power and the degree of modulation of the current (blend or mix). It is also influenced by three other factors: thickness of the cutting electrode, rate and depth of cutting and the impedance of the HF generator. With a conventional HF unit having an impedance of



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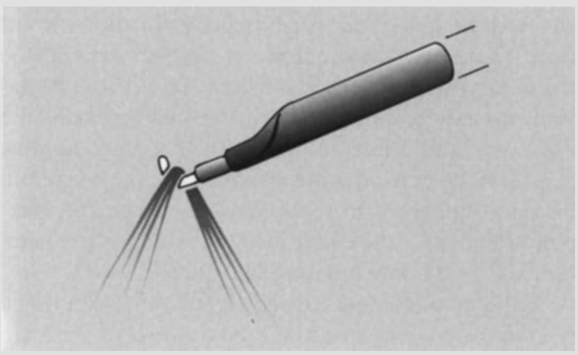

7.8

Fig. 7.7. Cutting of tissue planes with the electrosurgical hook knife is best performed using the heel of the instrument

Fig. 7.8. Dissection and division of adhesions is undertaken by lifting and stretching the structure inside the curvature of the knife before activating the blender current to achieve the cut and coagulate the edges. In general, however, division of adhesions is conducted with greater safety by the use of the scissors

250 ohm, fluctuations in the current on the output voltage and intensity of the electric arcs are produced by variations in the depth and rate of cutting. This may lead to carbonization of the tissue along the cut edges, particularly at the beginning and end of the cut. This problem, which is a major consideration in laparoscopic surgery, can be obviated by the use of HF surgical units which incorporate automatic control circuits. These ensure that the intensity of the electric arcs are kept constant irrespective of the cutting rate and depth. It is highly recommended that this type of automatic control unit is used in association with the electrosurgical hook knife in laparoscopic surgery.

Cutting with the electrosurgical hook knife is best done with the heel of the instrument (Fig. 7.7). During activation of the current, the usual precautions are taken to avoid diathermy damage to surrounding tissues. During dissection the tissue is lifted by the hook such that it becomes tented on the end of the instrument and pulled away from subjacent structures before the current is activated (Fig. 7.8). The same technique is used for performing oesophageal myotomy (see Chap. 11).

Stripping

This dissection technique is favoured in North America, particularly for dissection of the cystic duct and artery. It is performed by the use of an atraumatic dissecting forceps which is used to strip peritoneum and subjacent areolar and adipose tissue surrounding the structures. Though effective, the technique leads to oozing but is generally considered to be safe. It is also used for separating fine avascular adhesions.

Hydrojet Dissection

This is a simple but useful technique for elevation of tissue planes and is practised in performing pelvic lymphadenectomy. It is also used in the dissection of structures when these are surrounded by adipose tissue since the high-pressure jet breaks down the fat globules thereby exposing the required anatomy.

Laser Dissection

The physics and principles underlying the use of laser dissection and photocoagulation are outlined in Chap. 4. The three lasers used in laparoscopic surgery are argon, Nd:YAG, KTP and holmium:YAG. Most laparoscopic laser dissections are carried out using the contact mode (bare fibre) in preference to the free-beam mode because of the enhanced safety and the tactile feedback. The one major disadvantage of lasers during laparoscopic dissection is the risk of inadvertent damage from the "past pointing" or "shoot past" phenomenon where the laser energy penetrates through the intended target and damages deeper structures. Unintentional damage may also be inflicted by imperfect beam collimation in the non-contact mode and shake. Laser dissection is also slower than electrosurgical. It is claimed by some that smoke generation is less than with electrocautery although there is little evidence for this assertion.

Ultrasonic Dissection

Recently a laparoscopic probe for use with standard ultrasound dissecting machines used in open surgery has been introduced. Preliminary evaluation in animals suggests that it will be useful in the dissection of tissue planes, e. g. fatty cystic pedicle and separation of the gallbladder from the liver bed. However, further experience of its use in humans is required before a definite assessment of its usefulness can be made. The limitation of all ultrasound dissectors is that they have to incorporate straight tips.

Sharp Scalpel Dissection

Scalpels of various shapes can be introduced through 5.5-mm cannulae and can be used to incise organs such as the common bile duct (for supraduodenal exploration) and hollow viscera during the creation of anastomosis. Apart from this scalpel dissection has a very limited place in laparoscopic surgery and great care should be exercised during the introduction, use and withdrawal of these instruments. In addition to steel, diamond and ceramic knives are now available.

Haemostasis

One of the limitations of laparoscopic surgery is the control of bleeding, and, indeed, haemorrhage during laparoscopic and other forms of endoscopic operations is the most common reason for conversion to the open procedure. This applies particularly to cut, bleeding arteries which rapidly retract within surrounding adipose and connective tissues. In this context, the most important guideline is careful dissection with securement of blood vessels by whatever method is used prior to their being cut. In this form of surgery, the operator cannot afford to take chances because it is not possible to rapidly put a swab or finger on the bleeding point. Nonetheless, control of bleeding when it occurs is possible in many instances if the right technique is adopted. It is, however, best prevented by prior electrocoagulation, photocoagulation, ligature in continuity or clipping.

Electrocoagulation

Electrocoagulation is the mainstay for achieving haemostasis during endoscopic and laparoscopic dissection. Again, it is important to appreciate the principles underlying safe electrocoagulation of tissues. When an HF alternating electric current is applied specifically for endogenous heating of living tissue, the temperature rise is proportional to the specific electric resistance of the tissue, the duration of current flow and the square of the root mean square of the electrical current density. Largely because of the irregular current density distribution in the tissue, the temperature rises at different rates in various zones in the tissue. As the current density is largest in the zone of contact between the tissue and the electrode, the maximal temperature is reached there, with the temperature decreasing proportionately with the distance from the contact area. The safe feasibility of monopolar electrocoagulation depends on this phenomenon since the further away the tissue is from the contact area, the less likely the damage. By contrast, heating of the tissue in bipolar electrocautery is confined to the area between the two ends of the probe. Once the temperature of the tissue near the contact surface has reached boiling point, a layer of vapour forms between the tissue and the electrode which impedes further current flow. Thereafter the sequence of changes depends on the peak voltage. If this is less than 200 V, the coagulation process slows down until the tissue next to the electrode has dried out when further current flow ceases. If the current is not switched off, the coagulum becomes adherent to the electrode. When this happens, removal of the electrode will dislodge the coagulum and precipitate renewed bleeding.

If the peak voltage exceeds 200 V, once the tissue next to the contact area has dried out, electric arcs are produced which carbonize and puncture the coagulum, thereby causing the coagulation process to continue unabated until the generator is switched off or the dried-up coagulum is so thick that it resists further puncture by the electric arcs.

There are three coagulation modes which can be used: soft, forced and spray. There is no doubt that *soft coagulation* is the safest mode to use in ES, especially when administered in a bipolar fashion. As the peak voltage is less than 200 V, no electric arcs are generated between the coagulating electrode and the tissue during the entire process with elimination of tissue carbonization. Soft coagulation is recommended in laparoscopic surgery whenever monopolar or bipolar electrodes are brought into direct contact with tissue. As the reproducibility of the soft coagulation depth increases inversely with the impedance of the HF generator, a unit with automatic voltage control is ideal. Activation of the unit should cease during soft coagulation when vapour formation commences, as beyond this stage the coagulum will desiccate and become adherent to the probe. There are now generator units with an automatic de-activation of the HF current once the end of the coagulation process has been reached. These are ideal for laparoscopic soft coagulation because they eliminate the above problem and the risk of detachment of the coagulum on withdrawal of the probe.

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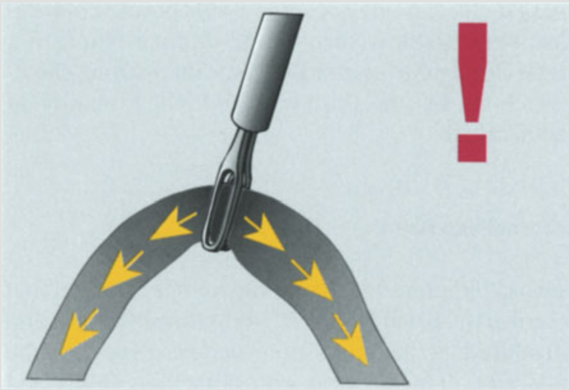

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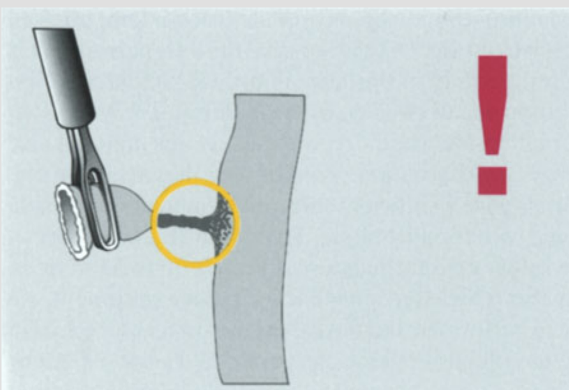


Fig. 7.9. During monopolar electrocautery, as the HF current flows through long segments of tissue with the same cross-section, the entire length of the structure may be electrocoagulated

Fig. 7.10. HF frequency current applied with the monopolar technique flows preferentially through narrow segments. Thus the coagulation starts at the point of constriction of the tissue and not at the point of contact with the electrode (*yellow circle*)

In *forced electrocoagulation,* high peak voltages are used (greater than 500 V) to generate electric arcs between the electrode and the tissue in order to obtain deep coagulation. Forced coagulation which is applied with thin or small electrodes (e.g. TUR) is unsuitable and dangerous in laparoscopic surgery.

Spray coagulation is a non-contact mode where long electric arcs are intentionally generated by strongly modulated HF voltages (few kilovolt) to surface coagulate raw bleeding areas or achieve haemostasis from inaccessible vessels. A recent innovation which is likely to enhance the scope of spray coagulation during endoscopic and laparoscopic surgery is the argon beamer for use with HF surgical units with automatic circuit control. In essence, this device emits a jet of argon gas in the middle of which is the tungsten electrode. In addition to conducting the electric arcs, the jet of gas, removes and dries the field of blood and fluid during the coagulation process. The big practical advantage of this form of spray coagulation is the great reduction in the depth of coagulation and elimination of the surface carbonization which is induced by standard conventional coagulation.

The measures needed to ensure safety and avoid complication during HF electrosurgery are outlined in Chap. 13. However, it is important to stress that bipolar coagulation is safer than monopolar and should be used whenever possible.

In using monopolar electrocautery it is important to appreciate that, if HF current flows through long segments of tissue with the same cross-section, the entire length of the structure may be electrocoagulated (Fig. 7.9). Furthermore, HF frequency current applied with the monopolar technique flows preferentially through narrow segments. Thus the coagulation starts at the point of constriction of the tissue and not at the point of contact with the electrode (Fig. 7.10).

Endocoagulator (Heater Probes)

The endocoagulator for use in laparoscopic surgery was developed by Semm. In this safe and ingenious device electricity is used to heat the operating tips of instruments such as the point coagulator and crocodile forceps. The destructive heat is then transferred to the tissue by direct conduction. The safety of the system lies in three respects. First, there is no direct contact between the electric current and the tissues; secondly, the coagulation temperature (90–120 °C) and the coagulation time can be preselected to avoid carbonization; and thirdly, the operating tips, because of their miniature mass, cool rapidly soon after the heating cycle is switched off, thereby preventing accidental damage from inadvertent contact with adjacent organs. The endocoagulation system is the safest form of coagulation in laparoscopic surgery and, by avoiding desiccation and vaporization, reduces adhesion formation.

Ligation in Continuity

As in open surgery large vessels can be ligated in continuity before being cut using the Roeder slip knot (see below). This knot is safe (in terms of its resistance to reverse slipping) only when tied with dry catgut. If the vessel or pedicle is large (greater than 3.0 mm), it should be doubly ligated with 1/0 catgut for increased safety. The Roeder knot works well only with catgut.

Clipping

The use of clips is described later on in this chapter. It is important, however, to stress that the correct clip size and direction of application (at right angles to the vessel) are crucial factors in the prevention of slippage and delayed bleeding.

Photocoagulation

Both free-beam and contact laser can be used for photocoagulation, although the latter (using a bare tip fibre) is more precise and safer, particularly in terms of the shoot-past phenomenon.

Arrest of Active Bleeding

If bleeding is encountered during the course of an endoscopic or laparoscopic operation the following sequence of measures must be followed:

1. If this consists of simple oozing, pressure by pledget swab or blunt tip of the palpating probe is instituted and the area then irrigated with warm heparinized saline. Any minor bleeding points can then be soft-contact coagulated if necessary.
2. Active arterial bleeding requires immediate precise grasping of the bleeding vessel with an insulated forceps. Often an extra part is required for suction of the area. The options are then to soft electrocoagulate the vessel (if less than 3.0 mm) or clip it proximal to the grasped point if large. However, if control is not rapidly achieved (within a few minutes), it is safer to convert to open operation.

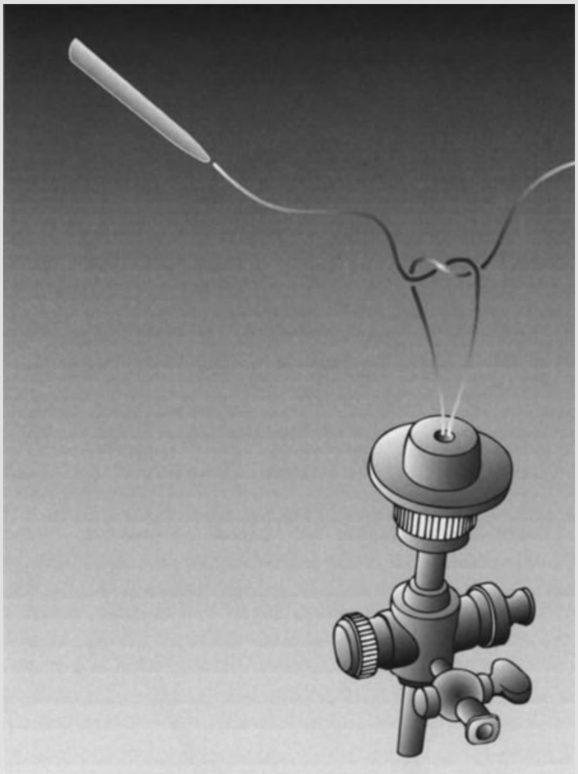
Knotting

Safe reliable knotting is crucial to tissue approximation. In laparoscopic surgery special techniques are required to achieve this purpose. Both internal and external knotting is possible after the acquisition of the necessary skills, which can only be obtained by practice on the bench trainer. Many surgeons who have recently taken up laparoscopic surgery rely exclusively on clipping to secure ductal structures and vessels. This is an unsatisfactory practice since situations are often encountered when it is not possible to clip a structure safely, either because it is too large or because the access is limited. In other circumstances, the use of metal clips may be undesirable because of long-term consequences such as the internalization of a metal clip used to secure the cystic duct during cholecystectomy. In time, this may lead to the formation of ductal calculi.

External Slip Knot

The most important external slip knot is based on that described by Roeder (Fig. 7.11a) for tonsillectomy and introduced by Semm in laparoscopic surgery in the mid-1970s. It works best with dry catgut (plain and chromic) and to a lesser extent with silk. We have investigated the safety (in terms of the tension required to induce reverse slipping) of the Roeder knot using an ex vivo test rig. Dry catgut gave the best performance, and the safety of this knot improved sixfold after hydration due to swelling of the material. The knot is acceptably safe when tied with silk as this material also swells with hydration. None of the other available materials gave a sufficient safety margin to allow reliable tying with this technique. The catgut Roeder knot can be safely used for ligation of vessels up to 3.0-mm diameter. This assertion is backed up by experiments we have performed and the experience of its use in Kiel in gynaecological operations performed since 1977. For larger vessels, the application of two loops is required to ensure safety. The modified Roeder knot (double hitch at the beginning and end) introduced by Melzer is a safe knot with polydioxanone and when tested in our laboratory was found to resist a tension of 1200 g. Other external slip knots are unreliable as they slip readily with tensions lower than 600 g.

Fig. 7.11. **a** Roeder slip knot. The knot has three components: *(1)* simple hitch; *(2)* three external winds; *(3)* locking hitch. **b** Melzer knot for polydioxanone



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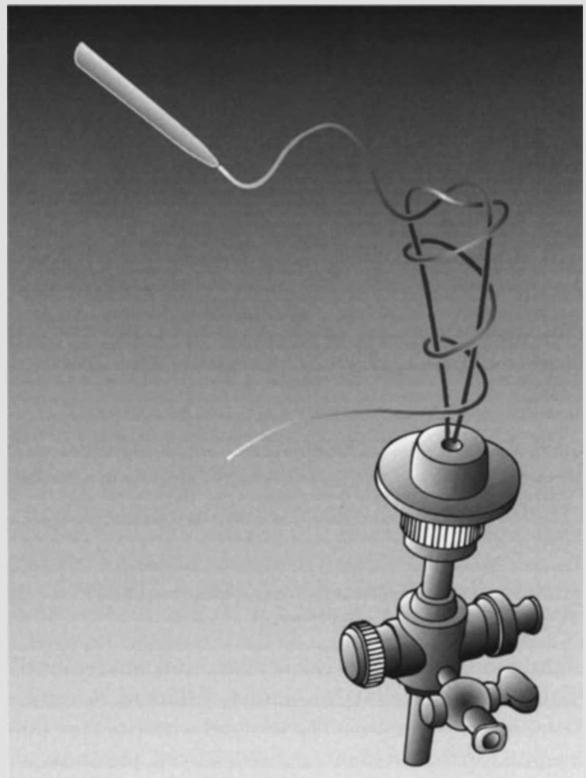

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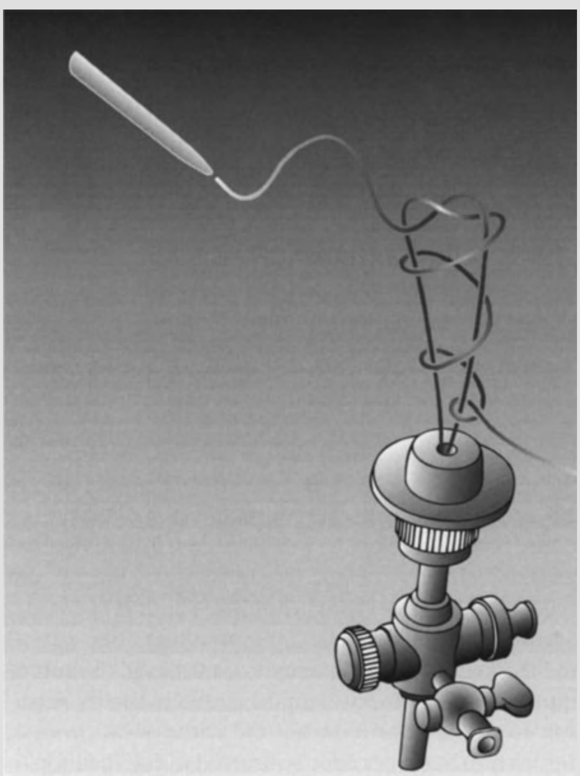

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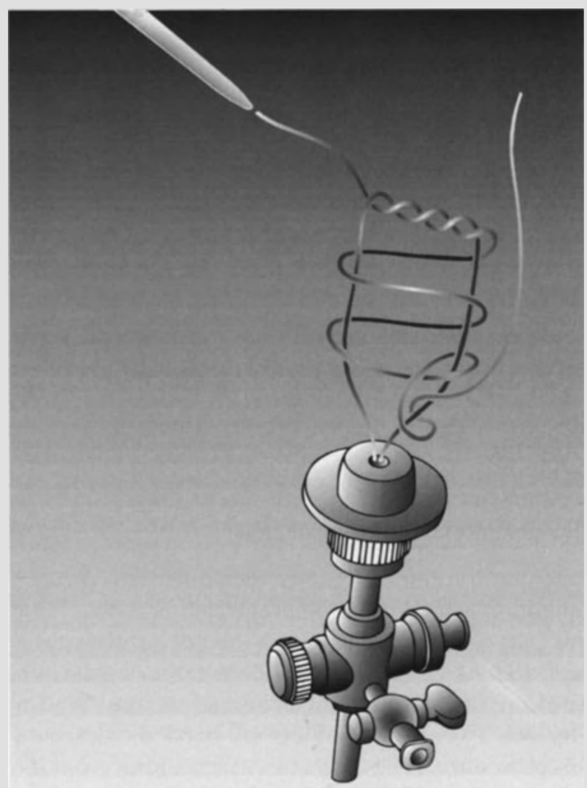

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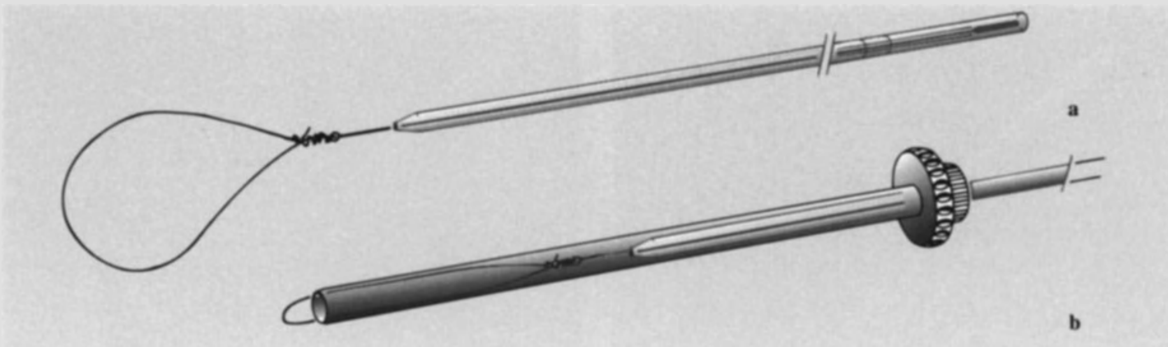


Fig. 7.12. **a** Preformed endoloop. **b** The endoloop is loaded into the suture applicator, and this is then introduced down a 5.5-mm cannula

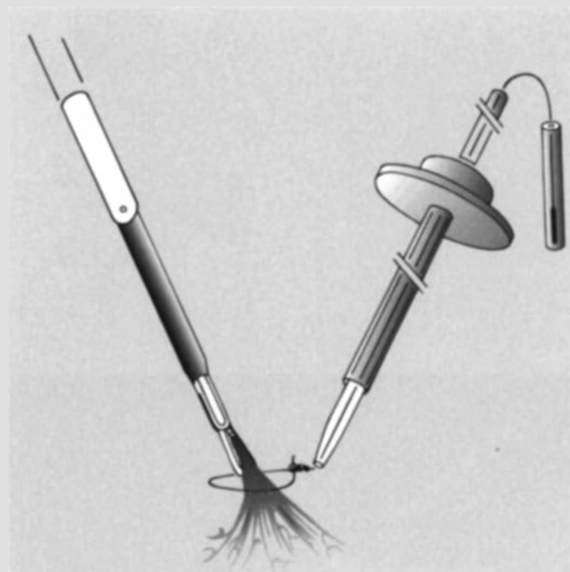


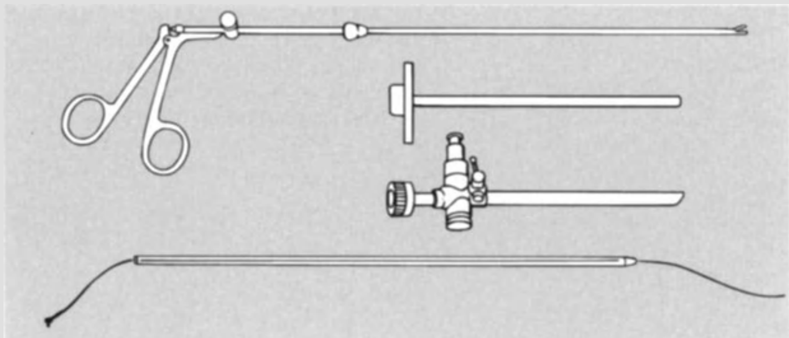
Fig. 7.13. After the loop is fed into the peritoneal cavity totally in a suture applicator, the loop is exteriorized from the latter by advancing the rod. A grasping forceps is placed inside the loop and used to pick up and tent the tissue inside the loop which is then tightened around it and locked firmly in place

Preformed Catgut Endoloops

Endoloops are based on the Roeder knot and are commercially available (Ethibinder, Ethicon, Surgitie, Auto Suture). The item is packaged with the long tail of endoloop threaded through a push-rod, the end segment of which is snapped off to release the end of the tail of the catgut. The endoloop is loaded into the suture applicator, and this is then introduced down a 5.5-mm cannula (Fig. 7.12). After the loop is fed into the peritoneal cavity totally inside a suture applicator, the loop is exteriorized from the latter by advancing the rod. A grasping forceps is placed inside the loop and is used to pick up and tent the tissue inside the loop which is then tightened around it and locked firmly in place (Fig. 7.13). This technique is suitable for dealing with fresh perforations of the gallbladder, for securing the base of the appendix during appendicectomy, for closure of a peritoneal gap and for closure of a wide cystic duct, although ligature in continuity is preferable in dealing with the last problem (see below).

Ligature in Continuity Using the Roeder External Knot

Ligature in continuity before the structure is divided cannot be achieved by the preformed endoloop. For this purpose a catgut suture is threaded through the push-rod which is loaded inside a suture applicator. The steps of this important technique are illustrated in Fig. 7.14. Two needle holders are needed to execute this procedure. A 3.0-mm one (which allows room for the suture lying alongside it within the suture applicator) is used to grasp the end of the suture (leaving the push-rod outside) and is inserted together with the suture applicator down a 5.5-mm cannula. The end of the suture is advanced by the needle holder around the desired pedicle and grasped momentarily by the 5.0-mm needle holder (inserted via another cannula) before it is transferred back to the 3.0-mm holder (Fig. 7.15, a) and then withdrawn to the exterior through the suture applicator. To prevent damage to the tissue by serration from the suture during the withdrawal process, the 5.0-mm needle holder is inserted inside the loop to take the tension and friction off the structure. Once the end of the suture emerges out of the cannula, the



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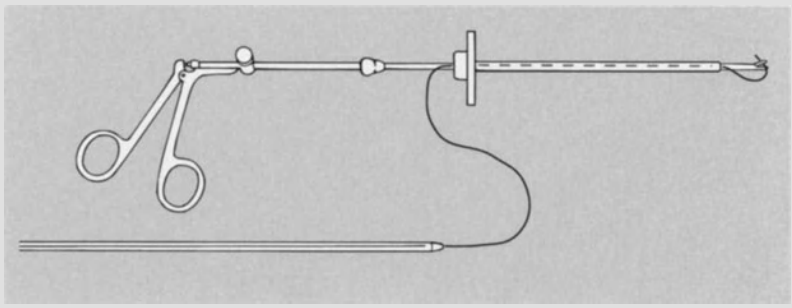

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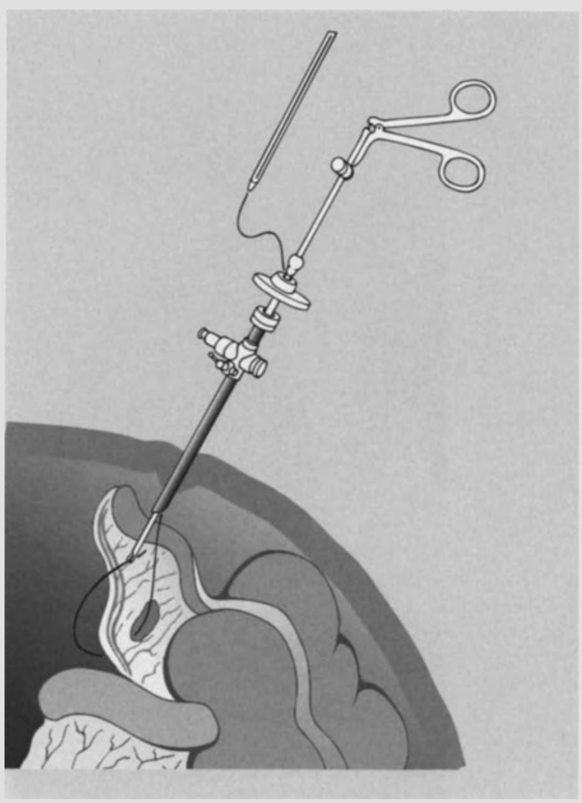

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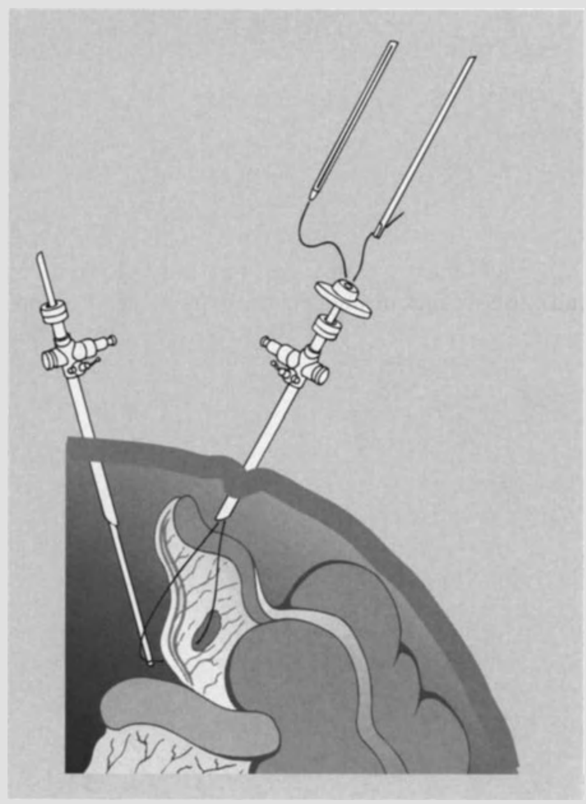
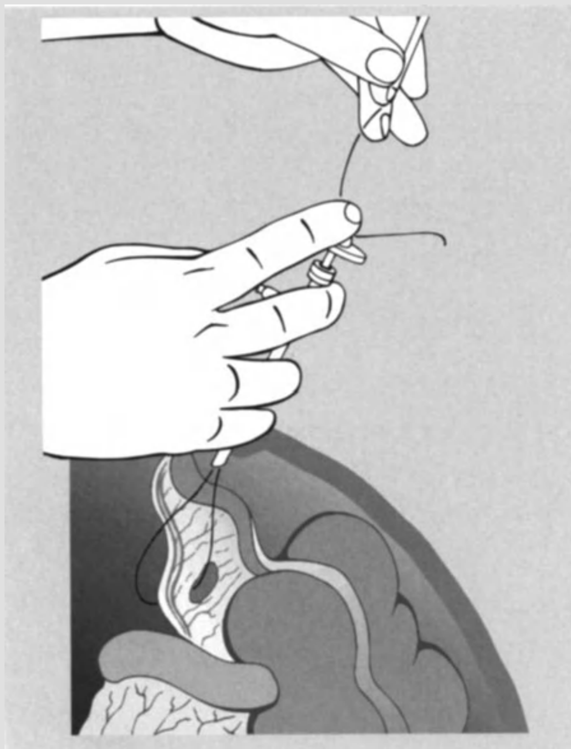


d

Fig. 7.14a–i. Steps involved in ligation in continuity with catgut using the external Roeder knot. **a** The instruments needed are: accessory 5.5-mm cannula, suture applicator, push-rod containing suture, 3.0-mm needle holder, hook scissors (not shown) and a grasping forceps. **b** Step 1: loading of suture applicator with 3.0-mm needle holder grasping the suture. **c** Step 2: insertion of the loaded suture applicator into the trocar and placement of the suture around the "structure". **d** Step 3: withdrawal of the suture through the suture applicator with grasping forceps preventing serration of the "structure"

Fig. 7.14. **e** Step 4: assistant's finger sealing the suture applicator. **f** Step 5: completed Roeder knot. **g** Step 6: knot engaged into the suture applicator. **h** Step 7: Roeder knot slipped down by the push-rod with counter-traction on the tail of the suture. **i** Step 8: final locking of the knot



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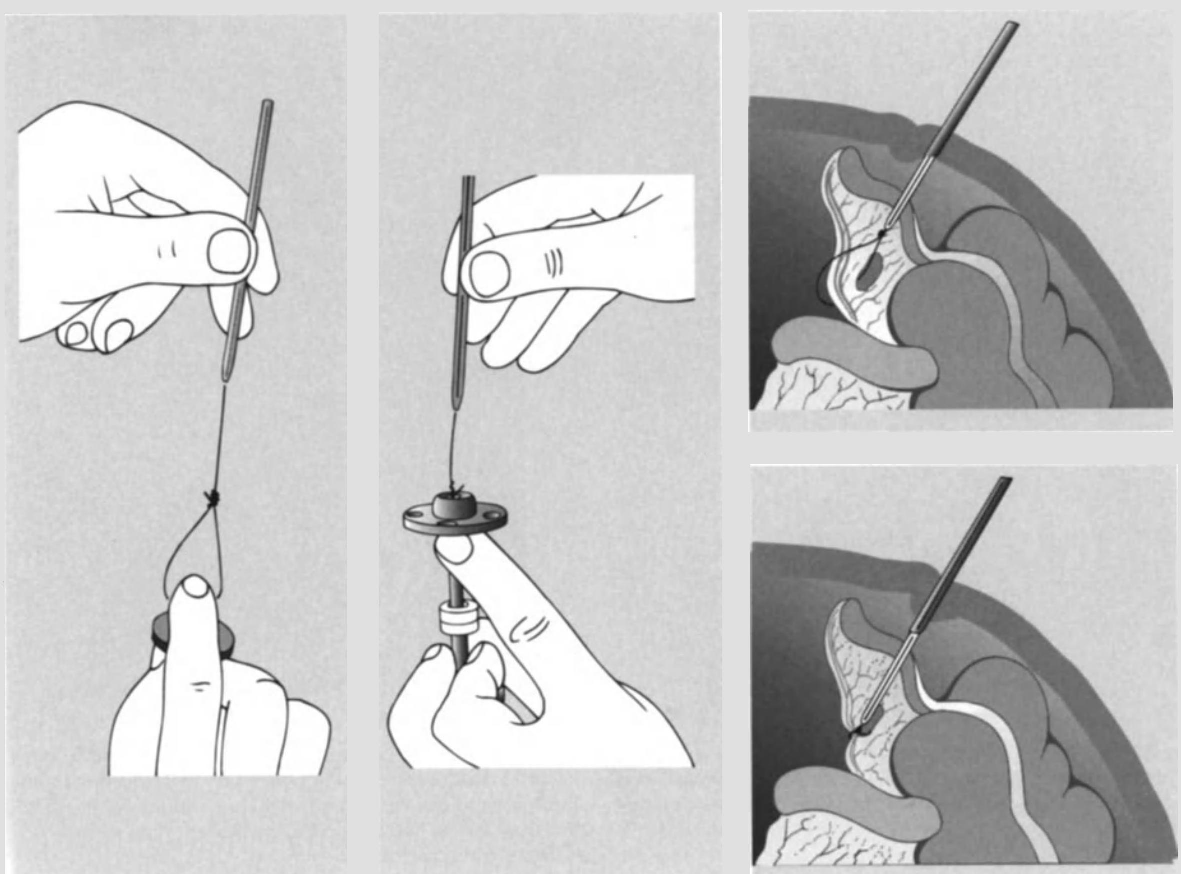
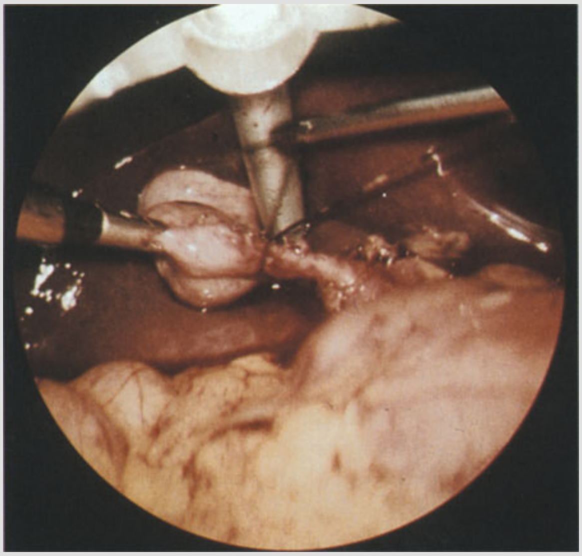


h

f, g **i**



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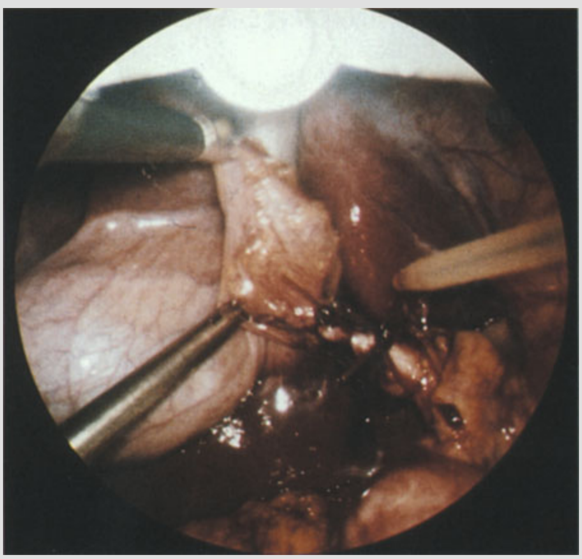


b

Fig. 7.15 a, b. Cystic duct ligated in continuity with chromic catgut using Roeder slip knot technique

assistant seals the suture applicator by finger occlusion to prevent gas leakage, whilst the Roeder knot is tied and trimmed before it is laid down to the desired site by the push-rod under visual control (Fig. 7.15, b). Once locked in place, the suture is cut with hook scissors.

PDS External Slip Knot

In 1991, in Tübingen, Germany, Melzer developed a special knot for PDS (polydioxanone, Ethicon). With synthetic materials, the usual external slip knot does not provide a sufficient safety margin in keeping the thread firmly locked around a vessel. This is due to their low friction coefficient, which allows reverse slipping. In order to increase the mechanical friction of the slip knot, Melzer modified the Roeder technique in a simple way. The tying procedure starts with a surgical knot. After three external winds and trimming as in Roeder's technique a doubled end knot finishes the procedure.

Table 7.1. Comparison of tension required for reverse slipping of external slip knots using catgut and PDS

USP	Suture type	Knot	Tension (N) Mean	after 10 s hydration Range
0	Dry plain got	Roeder	11.5	9.5–13.5
0	PDS	Ethicon	4.5	3.5–5.5
0	PDS	Roeder	10	8.5–11.5
0	PDS	Melzer	24.5	21–28
2-0	PDS	Melzer	25.25	22.5–31

The reverse slipping of this modified slip knot was tested and compared to several other types of external knots, including the Roeder loop using catgut (Table 7.1). The knots were pushed down and the loops locked around two PTFE cylinders using a force of 20 N. Thereafter the two cylinders were distracted with force increasing at a rate of about 1 N s^{-1} and the tension at which reverse slipping occurred was measured using an electronic strain gauge. All sutures were hydrated by immersion in pig's bile for 10 s – the average time a well-trained surgeon needs to cut the suture. PDS tied with the new technique gave the best results. 2-0 PDS thread can be stressed up to breaking point without the knot slipping in nearly every case.

Catgut shows increased safety once hydrated, but the required hydration time to reach maximum strength is longer.

The new knot is available commercially as a PDS Endo Loop, and detailed knotting instructions are printed on the sterile packages of PDS Endo Ligatur and PDS Endo Suture.

External Surgeon's Knot

The advantages of this technique include familiarity with its use in open surgery and applicability to all suture materials. The two ends of the ligature (or suture) are exteriorized inside a suture applicator or reducer tube (to avoid entanglement in the valve). Whilst the assistant puts a finger between the two strands on top of the suture applicator to prevent gas leaks, the first

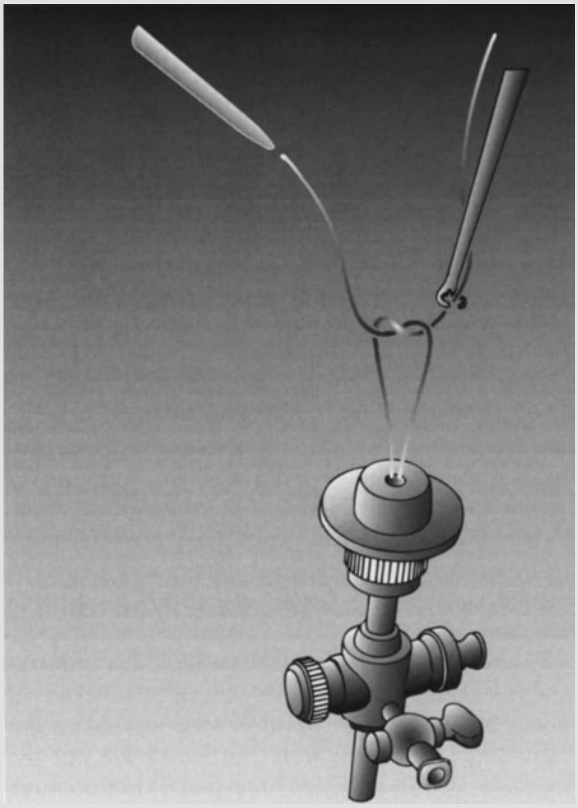


Fig. 7.16. Ring pusher used for external reef knotting (surgeon's knot) (Storz)

component of the surgeon's knot (double hitch) is fashioned. Whilst the two ends are kept taut, the hitch is slid by means of a slit circle metal pusher and locked in place by the knot pusher (Fig. 7.16). The second and third components of the surgeon's knot are fashioned externally, pushed down and firmly locked in a similar fashion. The author has used this knot both experimentally and clinically. Despite its obvious advantages, it has certain drawbacks, which are:

1. Some materials do not slide easily after creation of the first double hitch. This applies to silk and catgut and, to a lesser extent, to some of the synthetic materials such as polyamide. This problem can be overcome by using a single throw, but then it is difficult to lock the first component which becomes loose before the second hitch reaches it.
2. If the gap in the ring is too wide in relation to the suture, the ring can easily come off the "tightrope" during transit inside the suture applicator. This problem can, of course, be readily overcome by use of appropriately sized ring gaps to match the thickness of the suture being used.

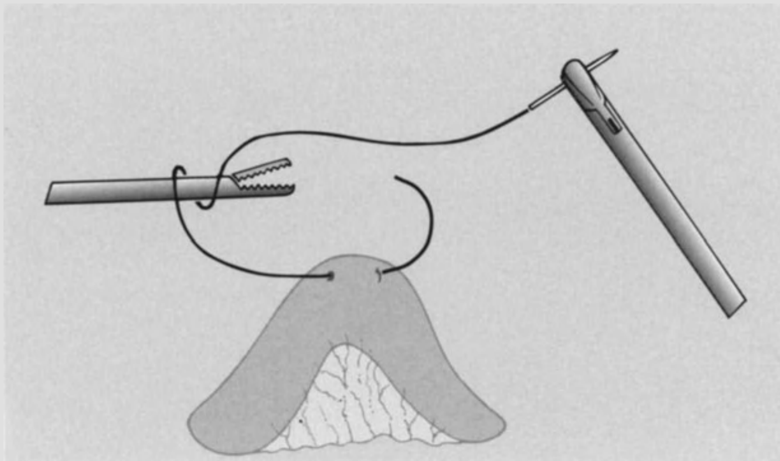
Internal Knots

Internal knots are used in relation to suturing more commonly than external knots. Irrespective of the method used, the number and type of locking throws will be governed by the type of suture material used. Internal knotting requires practice to be performed smoothly and quickly, and this is best achieved by use of the practice bench with foam or animal tissue specimens.

Standard Microsurgical Knot

Undoubtedly the microsurgical knot is the most difficult knot to execute in laparoscopic surgery. It requires a two-handed technique using two self-grasping needle holders of the Semm's type (usually 3.00 and 5.00 mm). In practice there are certain important points which the authors have found to be important in facilitating this task:

1. The suture must be short (not exceeding 10 cm).
2. The tail must be kept short and its tip placed in a position where it can be readily grasped.
3. If the tail is on the left, the long limb of the suture is grasped in the left needle holder and the suture wound on the right one, which can then be advanced with ease to the left to grasp the tail (Fig. 7.17).
4. It is easier to wind the suture on the receptive needle holder with the needle still attached and held near its tip. The needle is positioned parallel to the receptive needle holder and its butt pushed towards the needle holder as the suture is wound around the latter (Fig. 7.18). This is, of course, only possible with interrupted sutures and does not apply to continuous suturing. In any event, a double wind is necessary for the first throw to enable a certain amount of locking.
5. Following the double winding of the first component of the knot, the tail must be grasped as near to its tip as possible to facilitate sliding as the needle holders are separated to create the first hitch.
6. For secure knotting, the winding of the second component (single or double depending on material) of the knot must be in the reverse direction to the first and the winding of the third component identical to that of the first.



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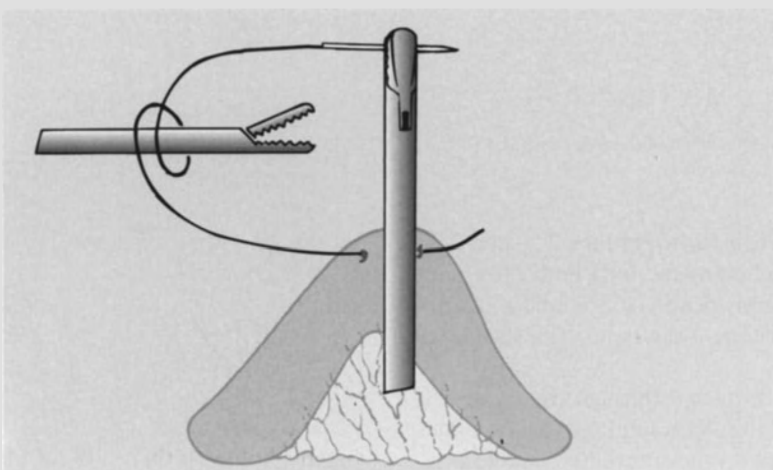


7.18

Fig. 7.17. Internal knotting using the standard microsurgical technique. Positioning and use of the active and passive needle holders in relation to the location of the tail. If this is on the left side, the long limb of the suture is grasped in the left needle holder and vice versa

Fig. 7.18. Internal microsurgical knotting. Technique for facilitating winding of the suture around the receptive needle holder with the needle still attached and held near its tip

Dundee Internal Jamming Knot

The Dundee internal jamming knot is quicker and easier to execute than the standard microsurgical knot and was developed to facilitate continuous suturing. It has four components:

1. External jamming slip loop knot (JSLK)
2. Reversal of needle through loop
3. Slide of loop (from the tail) and locking (from the standing part)
4. Restraining hitch. The mirror image of this knot which slides from the standing part and is locked from the tail is known as the Crabber's eye knot.

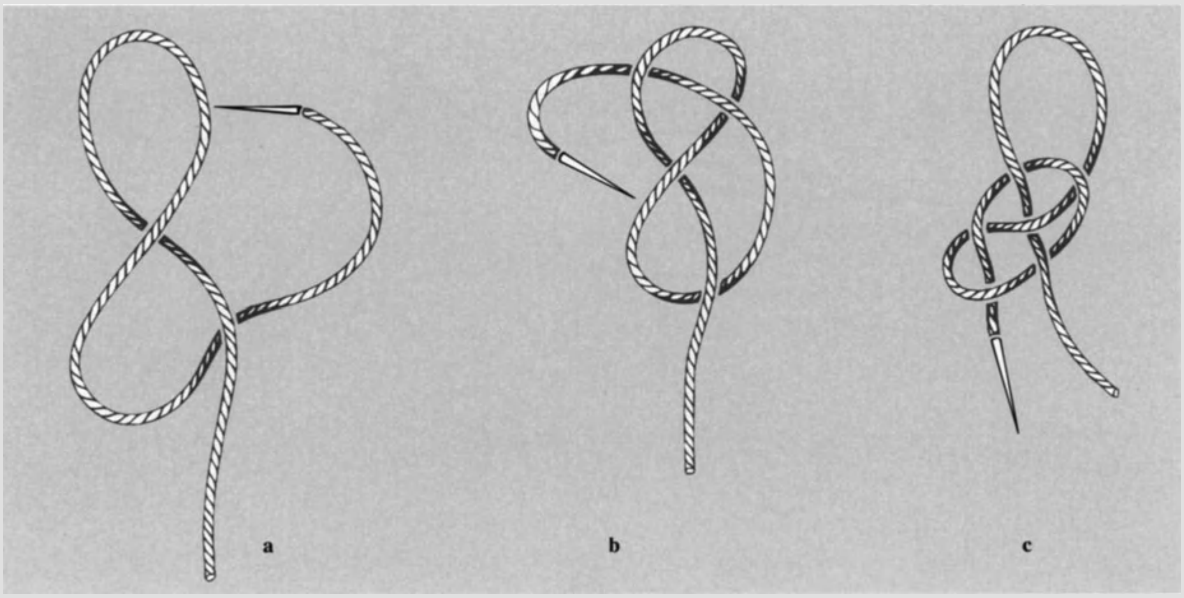


Fig. 7.19 a–c. Steps in the execution of the external JSLK

The external JSLK is shown in Figs. 7.19 and 7.20. The suture is grasped along the long limb ("standing part" in knotting jargon) close to the needle and introduced inside the peritoneal cavity inside a suture applicator.

After the needle is passed through the tissue, the suture is pulled until the JSLK impinges on the tissue. Whilst tension is kept on the suture, the needle is reversed and passed through the loop, bringing the length of the suture alongside the knot (Fig. 7.21). The suture is then grasped close to the loop and the tail pulled in the opposite direction to slide the loop on the suture. The knot is "jammed" by pulling on the suture whilst applying counter-traction on the knot by the needle holder (Fig. 7.22).

The restraining hitch is only necessary for interrupted knots tied with this technique (Fig. 7.23). Only one such hitch is necessary if silk is used, but other materials, such as polyamide, which do not lock as well as silk require two restraining hitches.

Aberdeen Knot

This is the best terminal knot for ending a continuous suture line. After three interlocking loops have been made and locked, the suture is introduced through the last loop before traction is applied to close the loop and secure the knot.

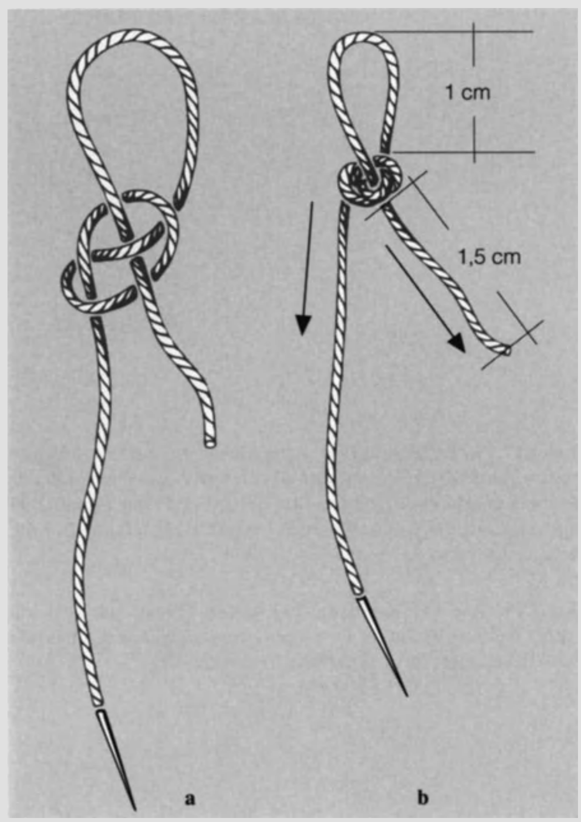


Fig. 7.20 a, b. When fashioned (**a**), the JSLK should be slipped from the tail to form a 1.0-cm bind or loop after which the tail is cut short (1.5 cm) (**b**)

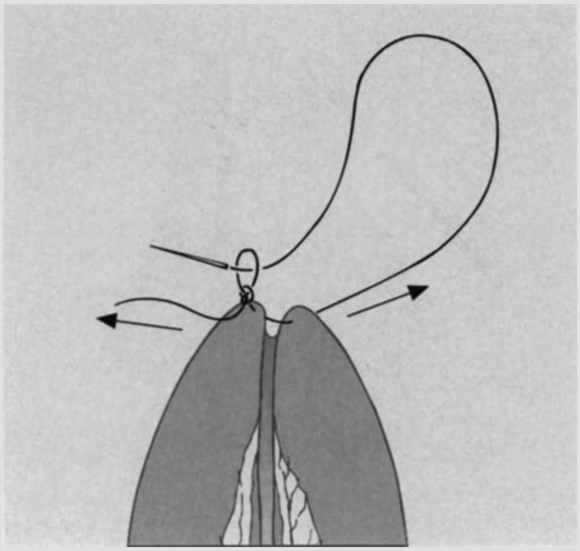


Fig. 7.21. After the needle is passed through the tissue, the suture is pulled until the JSLK impinges on the tissue. Whilst tension is kept on the suture, the needle is reversed and passed through the loop bringing the length of the suture on the side of the knot

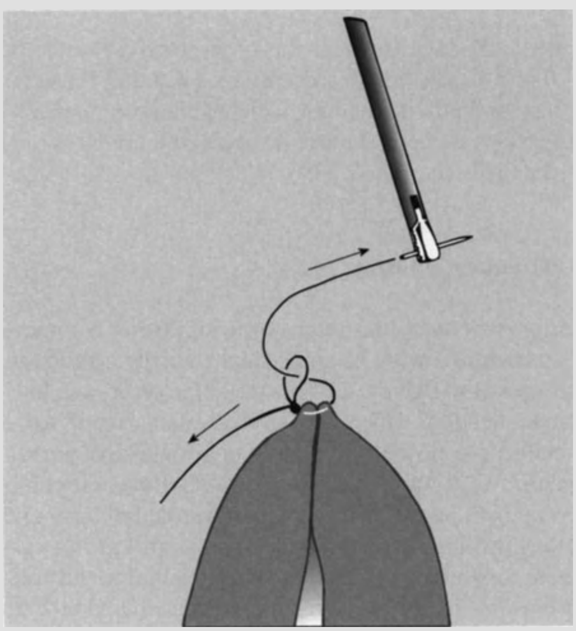


Fig. 7.22. The suture is then grasped close to the loop and the tail pulled in the opposite direction to slide the loop on the suture. The knot is "jammed" by pulling on the suture whilst applying counter-traction on the knot by the needle holder

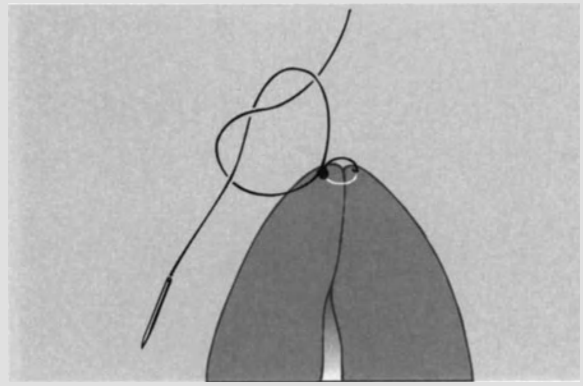


Fig. 7.23. For interrupted suturing, one or two restraining hitches are used (depending on the material) to secure the knot

Clips and Knot Substitutes

Non-absorbable metal clips (titanium) are available in various sizes. As in open surgery, selection of the appropriately sized clip for the pedicle in question is important. Care must be taken during their application, and a second clip should be used whenever considered necessary. Recently a preloaded clip applicator with automatic clip delivery to the jaws has become available (Endoclip, American AutoStapler). This instrument allows rapid, precise and repeated clipping without the need of withdrawing the instrument to load it, thereby speeding the procedure considerably.

One of the reservations with clips has been their liability to slip, especially if they are not of the right size in relation to the structure or have not been applied at right angles to its long axis and traction is applied to the clipped structure. They also interfere with both computed tomography and magnetic resonance imaging. Absorbable polydioxanone clips provide an attractive alternative to metal ones. Applicators designed to allow their laparoscopic use are available. Again, clip selection is important to match the size of the pedicle. If the clip applied is too small, the tissue will overlap the locking mechanism, which will not operate. On the other hand, a clip which is too large will not anchor securely and tends to slip off the pedicle. Absorption of these clips takes about 6 months.

Some surgeons use clips on the end of sutures instead of knots (Fig. 7.24). Whilst undoubtedly quicker, this practice is unsafe as the grip on the suture material by the clip is not secure enough, and it comes off easily with the minimum of traction. The only clip which is strong enough to hold the suture is made of silver, and this is used in endoluminal rectal surgery (see

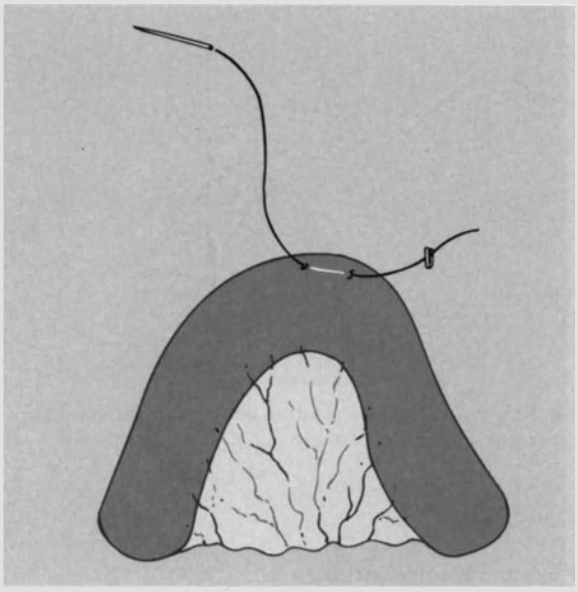


Fig. 7.24. Metal clip at the end of a suture which is used instead of knotting during continuous suturing by some surgeons. This method is unreliable as the minimum of traction on the suture results in the clip slipping off

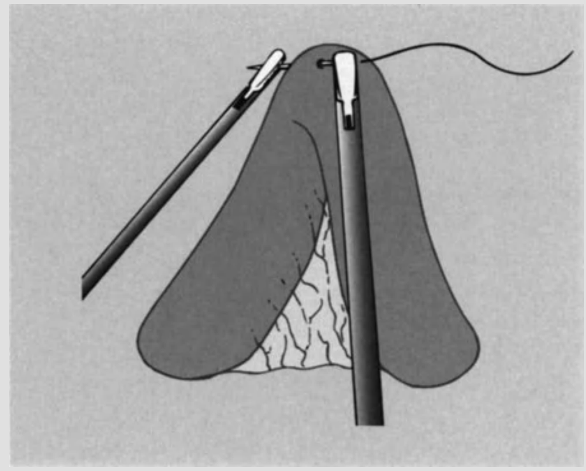


Fig. 7.25. The basic technique of suturing uses two needle holders. The 5.0-mm needle holder is used to effect needle passage through the tissue (active) on to the 3.0-mm needle holder (receptive). The latter is then used to grasp and pull the needle which is then regrasped by the 5.0-mm needle holder just before it emerges fully from the tissue

Chap. 25). Resorbable clips with similar grip strength are being developed.

Laparoscopic Suturing

Suturing requires considerable practice on a trainer. There is considerable scope for further development with respect to atraumatic sutures, needles, holders and temporary occlusion devices for laparoscopic suturing of organs.

The sutures must be atraumatic and the needle straight or only curved at the tip (ski-shaped) to facilitate grasping by the needle holder and passage of the needle through the tissue. The suture, which must be short (not exceeding 10.0 cm), is grasped near the needle by a 3.0-mm needle holder and introduced into the peritoneal cavity inside a suture applicator from the left side. A 5.00-mm needle holder inserted through the right side is used to grasp the needle close to its butt. The tip of the needle is held up towards the abdominal wall until the exact site of suture commencement is decided. Both interrupted and continuous suturing is possible, the latter being easier and quicker.

The basic technique of suturing uses two needle holders. The 5.0-mm needle holder is used to effect needle passage through the tissue (active) onto the 3.0-mm needle holder (receptive). The latter is used to grasp and pull the needle, which is then regrasped by the 5.0-mm needle holder just before it emerges fully from the tissue (Fig. 7.25).

Continuous Suturing

At present most continuous suturing is most commonly performed with 30-mm straight-needle atraumatic sutures although the authors mounted on 30-mm half-circle needles which are straightened except for a small curve close to the needle tip. For ease of performance, continuous suturing requires three cannulae, two positioned such that the two needle holders meet along the line of the intended anastomosis at right angles, and the third, which is sited cephalad to the area, is used by the assistant to grasp the suture and take up the slack after each needle passage. The initial terminal knot (the standard microsurgical reef knot or the Dundee knot with preformed jamming loop) is tied internally. With each needle passage the assistant picks up the slack and keeps uniform tension on the suture line. This has the added advantage of tenting and stabilizing the tissues, thereby facilitating needle passage (Fig. 7.26). At times one runs out of suture length be-

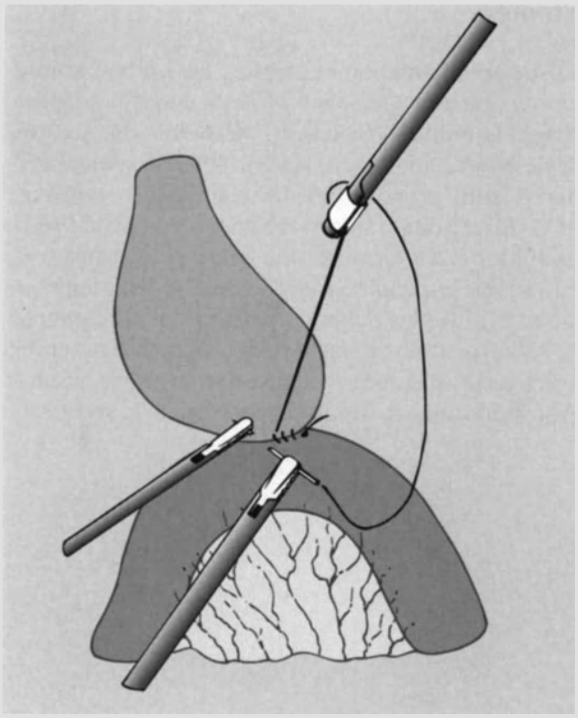


Fig. 7.26. Technique of continuous suturing. After each run, the assistant picks up the slack and ensures that the correct tension is kept on the suture line. The stitches are of the seromuscular type. A special suture holder with rubber-shod jaws is used to hold tension on the suture line (Storz)

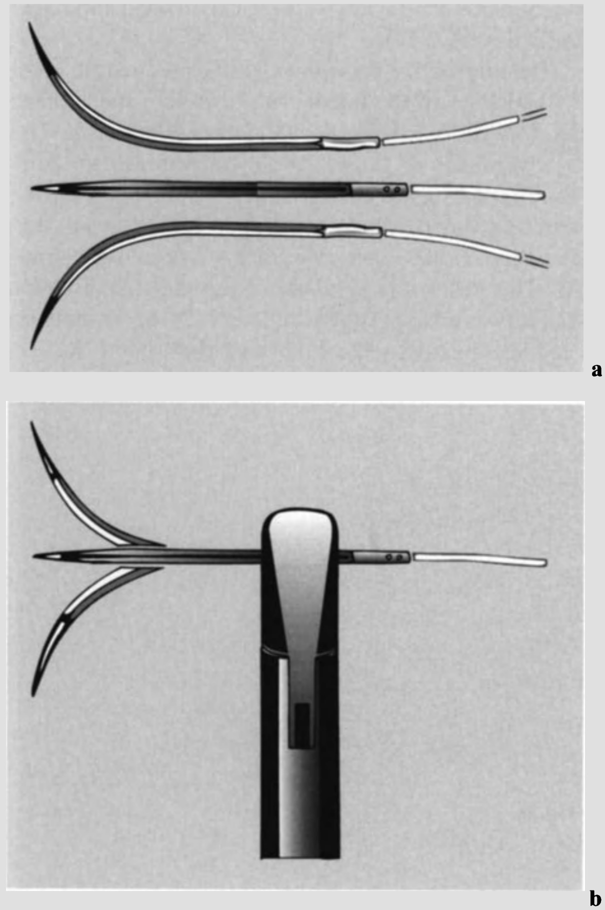


Fig. 7.27. **a** Endo-ski needle which eliminates the problem of needle swivel during laparoscopic suturing by having a triangular shaft. **b** The needle locks in one of three positions within the jaws of a Semm needle holder

fore completion of the suture line. In this eventuality, whilst tension is kept on the suture by the assistant, a new suture is inserted through the tissue and an internal knot tied leaving the tail longer than usual (2.0 cm). This is then tied to the preceding suture.

We have adopted this technique for fashioning cholecystojejunostomy and gastroenterostomy. The posterior suture line is completed with the viscera unopened taking deep seromuscular bites. The opening of the adjacent organs is the made with diathermy. Thereafter the anterior layer is sutured using the same technique. During these experiments we have observed minimal leakage of intestinal contents from the small bowel. This may be related to the high intra-abdominal pressure which compresses the bowel. Leakage from the stomach, however, still occurs, presumably because of the thicker walls and temporary occlusive devices are needed: laparoscopic tissue clamps or occlusive balloons (inserted through a small stab wound in the stomach). A fluid-containing organ such as the gallbladder is aspirated prior to the construction of an anastomosis.

Technical Problems with Current Suturing Instruments

The Semm's needle holders described above have one major disadvantage. The configuration of and the grip by the jaws on the needle shaft, though adequate enough to prevent needle slide during suturing, is not firm enough to prevent needle swivel. This makes it difficult to use needles with any significant curvature, and current straight needles have to be used. The limitation of the straight needle in ensuring a smooth glide through the tissues is well known. We have overcome this problem by the design of atraumatic sutures (Vicryl silk, and Nuralon) mounted on "ski needles" which are round bodied near the slightly curved tip and triangular along the straight shaft (Ethicon, USSC). The needle is gripped along the triangular shaft and locks in one of three positions inside the jaws of a Semm's needle holder: vertical, foward and backward tilt (Fig. 7.27).

The alternative is the use of the Cook needle holders which grasp the needle by a different mechanism and totally abolish the problem of needle swivel. The disadvantages of these needle holders are twofold. The first relates to the difficulty of internal knotting with these instruments, and the second is that a particular needle holder can only grasp the needle at one angle. This necessitates the use of three needle holders: standard version (right-angled), left-hand version (needle angled to the left) and right-hand version (needle angled to the right).

Staplers

Tissue approximation by stapling devices will considerably enhance the scope of gastrointestinal laparoscopic surgery. At present, however, the existing devices have limited applicability. The recently introduced AutoSuture Endo GIA laparoscopic stapler applies clips on either side over a distance of 3.0 cm and is useful for closure/transection of the stump during laparoscopic appendicectomy, in dealing with lung bullae and for wedge pulmonary resections. Undoubtedly, however, this stapling device has further potential, and it is currently being evaluated for the execution of gastrointestinal anastomoses and colonic resections.

Part II: Thoracic Procedures

8 General Principles of Thoracoscopic Surgery

A. Cuschieri

Introduction

There is no doubt that the substantial benefit to the patient resulting from thoracoscopic surgery emanates, to a large extent, from the avoidance of a thoracotomy. Apart from the immediate consequences of thoracotomy which often precipitate cardiorespiratory decompensation and require postoperative ventilatory and inotropic support, the recovery period following a thoracotomy extends over a period of several months, particularly in elderly patients and those with co-existing cardiac disease. Post-thoracotomy pain, including intercostal neuralgia, is a very common occurrence. It detracts from the benefit of the operation and usually requires prolonged treatment or referral to pain clinics. In addition, scapular fixation to the chest wall and the development of a frozen shoulder are frequently encountered and necessitate active treatment.

Instrumentation and Approaches

Currently the instrumentation used is the same as that for laparoscopic surgery (see Chap. 2). However, specific thoracic instrumentation entailing the use of curved instruments is currently being developed (Storz) and will facilitate the surgical manoeuvres. In addition to the basic operating instruments, the following equipment is essential: 5.0- and 8.0- or 10.0-mm 30° forward-viewing telescopes, xenon or halide light source, electronic insufflator, endocamera, efficient irrigating/suction system and electrosurgical generator preferably with automatic circuit to ensure uniform coagulation during use of blender current and with monopolar and bipolar output facilities.

There are three basic approaches to thoracoscopic surgery: unipuncture, multipuncture and mediastinal.

Unipuncture Approach

This was pioneered by Wittmoser for thoracoscopic and retroperitoneal work. A single cannula is used to accommodate the optic and instruments including electrocautery probes and suction/irrigation (Fig. 8.1). It is ideally suited to the execution of denervation procedures such as sympathectomy and vagotomy.

Multipuncture Approach

This was developed in Dundee. In addition to a separate cannula for the telescope (placed inferiorly), three or four accessory trocar cannulae are inserted under vision to accommodate the instruments needed for two-handed dissection. This approach is required for the performance of pleurectomy, oesophageal dissection and oesophageal myotomy (see Chaps. 10, 11). Flexible cannulae are much preferable to rigid ones in thoracoscopic surgery.

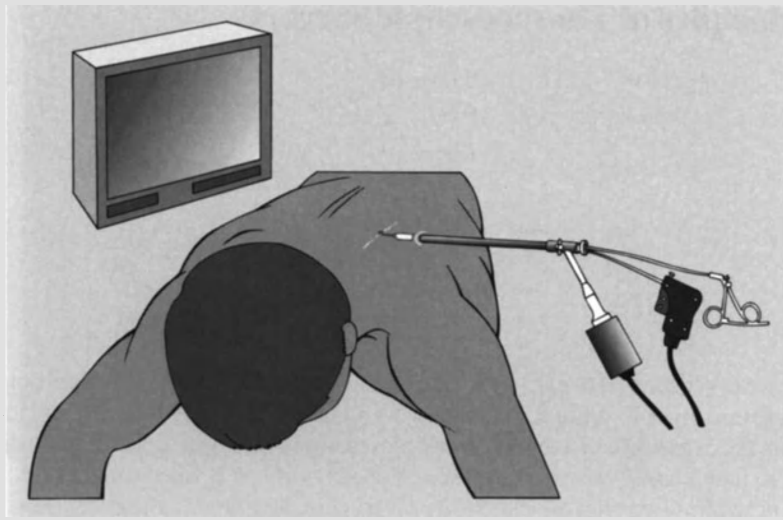
Mediastinal Approach

This approach was developed by Buess et al. The mediastinum is accessed through a standard cervical incision along the anterior margin of the left sternomastoid muscle by the use of a specially designed operating mediastinoscope. The technique is used for the perivisceral dissection of the oesophagus (see Chap. 12).

Anaesthesia, Patient Positioning and Monitoring

Anaesthesia

General endotracheal anaesthesia is necessary. Unless there is a specific indication, a double lumen endotracheal tube (Carlen's) is not required, and the standard



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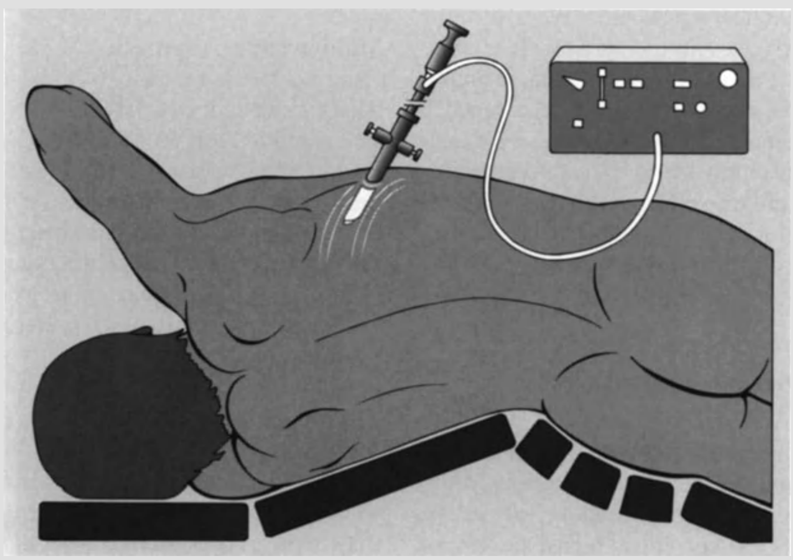


8.2

Fig. 8.1. Unipuncture system of Wittmoser

Fig. 8.2. Position of the patient for thoracoscopic surgery. The standard posterolateral position is used with the arm well abducted and the table split such that the intercostal spaces are opened to their fullest extent

endotracheal single lumen tube is sufficient as collapse of the lung is achieved by varying the inflow of gas and the insufflation pressure (see below).

Patient Positioning

For thoracoscopic work, particularly when the multiple puncture technique is used, it is essential to position the patient in such a way as to obtain maximal superior displacement of the scapula and maximal widening of the intercostal spaces. This is achieved by using the standard prone posterolateral thoracotomy position with the arm well abducted and the table split such that the ribs are splayed out to the fullest extent possible (Fig. 8.2). The positioning of the patient for endoscopic oesophagectomy is quite different and is dealt with in Chap. 12.

Patient Monitoring

Intraoperative continuous monitoring of the cardiovascular system and gas exchange are essential. The cardiovascular parameters which must be monitored are: ECG, arterial blood pressure and central venous pressure. These are crucial for the early detection of arrythmias and the onset of a low-output state which may occur due to the raised intrathoracic pressure. A Swan-Ganz catheter (with thermistor) for the determination of wedge pulmonary artery pressure and estimation of cardiac performance is inserted in patients with myocardial disease. Gas exchange is monitored by pulse oximetry and end-tidal CO_2. Blood gas analysis is undertaken whenever considered necessary during the course of the operation.

Cannulae Placement for Multipuncture Approach and CO_2 Insufflation

In thoracoscopic surgery, there is no special advantage to the use of sheathed disposable trocar cannulae as the technique for initial insertion is different and all the remaining cannulae are inserted under visual control.

In the multipuncture approach, four cannulae (sometimes five) are used (Fig. 8.3). The inferior two are 11.5 mm in diameter for use of the 10.0-mm 30° forward-oblique telescope and insertion of clip applicator and pledget swab for blunt dissection. The upper two cannulae, both 5.5 mm, are used for the insertion of the operating instruments such as grasping forceps, scissors, etc. Siting of these access cannulae is critical so that by moving the viewing telescope from the anterior to posterior position, exposure as well as instrumental access is available to the entire chest cavity and its contents.

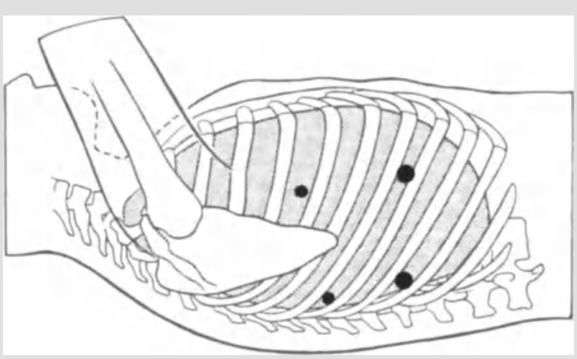


Fig. 8.3. The multipuncture approach for thoracoscopic lung and oesophageal surgery. A minimum of four trocar and cannula assemblies are used

Insertion of Initial Cannula

Unless the lung is collapsed or the patient has an indwelling intercostal drain, the initial cannula (anterior upper 5.5-mm) must be inserted under direct vision using a special technique designed to abolish the risk of damage to the lung parenchyma. The steps involved are:

1. Through a small skin stab wound, the 5.5-mm trocar and cannula assembly is advanced through the subcutaneous tissue into the intercostal muscle layer (Fig. 8.4). The trocar is then removed, and a 5.0-mm telescope is inserted, and the cannula is connected to the gas line set at the lowest inflation rate and an inflation pressure which must not exceed 6 mm Hg.
2. By rotation and gradual advancement of the cannula ahead of the optic, the subpleural space is reached (Fig. 8.5). If there are no adhesions binding the parietal pleura to the lung parenchyma, a translucent film with fine vessels is seen. This indicates a safe window through which the oblique tip of the cannula can be further advanced with a to-and-fro rotational movement.
3. When the cannula breaches the parietal pleura, the combined effect of the insufflating gas pressure and lung compliance results in collapse of the underlying lung away from the cannula tip, at which point the telescope is advanced for inspection of the pleural cavity (Fig. 8.6). In the presence of adhesions binding the lung to the parietal pleura, the inspection of the latter by the telescope in the extrapleural space identifies a dull opaque appearance. In this instance, the cannula direction is changed or the site altered until a safe window is found. The above procedure is unnecessary in patients with an indwelling intercostal drain. In this instance, the chest tube is connected to the gas inflow from the electronic insufflator set at the minimal flow rate and a pressure of 6.0 mm Hg. The upper anterior 5.5-mm trocar and cannula is then inserted in the standard fashion. The gas line is transferred to the cannula and the chest drain removed. The 5.0-mm optic is introduced for initial inspection of the pleural cavity and the insertion of the other cannulae.

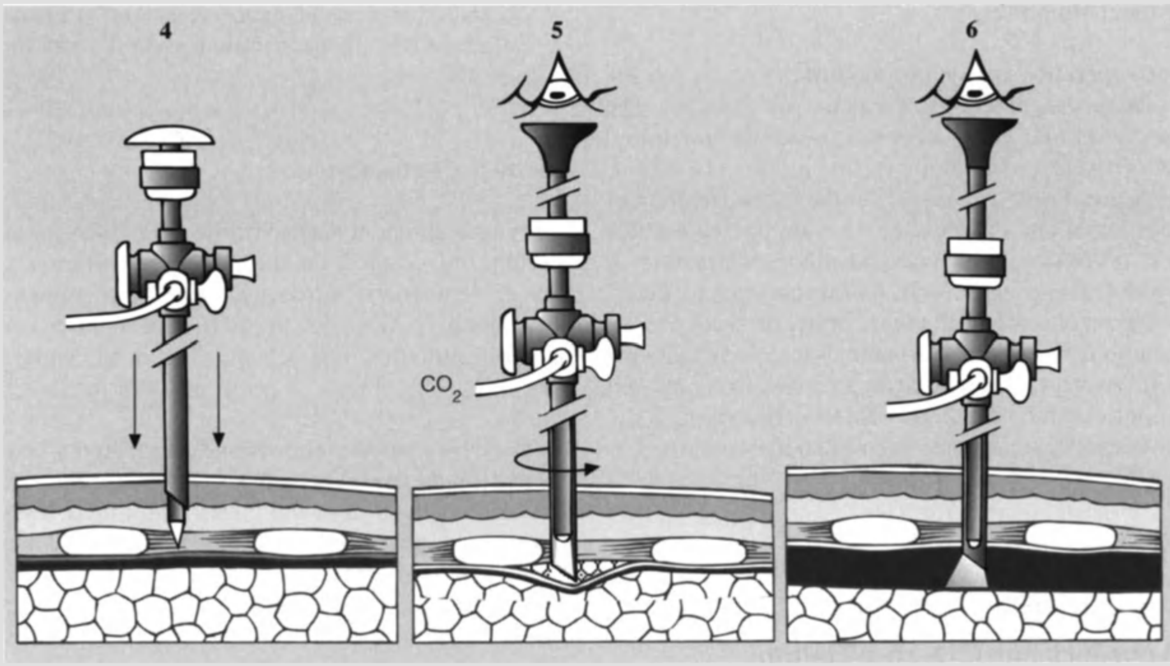


Fig. 8.4. The 5.5-mm trocar and cannula assembly is advanced through the subcutaneous tissue into the intercostal muscle layer. The trocar is then removed, and a 5.0-mm telescope is inserted

Fig. 8.5. By rotation and gradual advancement of the cannula ahead of the optic, the subpleural space is reached. If there are no adhesions binding the parietal pleura to the lung parenchyma, a translucent film with fine vessels is seen. This indicates a safe window through which the oblique tip of the cannula can be further advanced with a to-and-fro rotational movement

Fig. 8.6. When the cannula breaches the parietal pleura, the combined effect of the insufflating gas pressure and lung compliance results in collapse of the underlying lung away from the cannula tip, at which point the telescope is advanced for inspection of the pleural cavity

CO_2 Insufflation

The main purpose of CO_2 insufflation in thoracoscopic surgery is to collapse the lung. This is achieved by varying the amount of gas flow into and pressure within the thoracic cavity. In achieving this objective the pressure achieved within the hemithorax must not exceed 6.0 mm Hg as otherwise mediastinal shift and a low cardiac output ensue. In addition, the gas inflow should never exceed 1.0 litre a minute. It is of paramount importance in terms of patient safety that thoracoscopic surgery is conducted with full cardiac monitoring as outlined above. As the pulmonary parenchyma is not mechanically handled by this pneumatic compression, re-expansion of the lung is immediate after the procedure is completed.

Dissection, Haemostasis and Tissue Approximation

Undoubtedly the best operating optic for thoracoscopic work is the 30° forward-oblique 10.0-mm telescope since this allows the surgeon to look down on the operative field and permits rapid changes of the viewing angle by rotation of the telescope. For mediastinal and basal work the 45° optic may be needed. As the procedure progresses, the position of the telescope and dissecting instruments may need to be changed to permit continued smooth dissection.

The basic surgical techniques of thoracoscopic surgery require a two-handed approach and are based on the same principles outlined in Chaps. 7 and 13. Lung bullae are best ligated with preformed endoloops of chromic catgut. In thoracoscopic work, electrocoagulation is best applied in the bipolar mode. Direct aortic branches to the oesophagus should be clipped rather than coagulated whenever possible. In any event, haemostasis has to be meticulous as even minor oozing rapidly obscures the view by collecting in the mediastinal gutter. Irrigation with warm heparinized saline is often needed to achieve a clear field.

Synchronous Flexible Endoscopy

The concomitant use of a flexible oblique viewing endoscope is of considerable help in thoracoscopic surgery on the oesophagus. Particularly when approached from the left side, the oesophagus lies deep in the aorto-vertebral gutter and, although there are distinct anatomical landmarks, it is not easily visualized at the start of the procedure. In addition, any minor oozing gravitates in the gutter, further obscuring the visualization of the organ.

The concomitant use of a flexible endoscope overcomes both problems. The endoscope is inserted at the start of the procedure and the tip of the instrument advanced to the oesophagogastric junction. Insufflation is kept to a minimum, and the light is left switched on. The lower end of the oesophagus is then easily identified by transillumination right at the start of the dissection (see Chap. 11). The dissection is considerably facilitated when the oesophagus is lifted up out of the aortovertebral gutter by turning the end of the flexible endoscope upwards (see Chap. 11). As the operation progresses, subsequent segments of the gullet are lifted in this fashion.

Intercostal Drainage

Intercostal underwater seal drainage is advisable after every thoracoscopic procedure and mandatory after ligation of blebs and pleurectomy for pneumothorax. The drain is inserted via the anterior 11.5-mm cannula site under vision to ensure accurate placement in the desired position. As the technique avoids the need for lung retraction, patchy collapse and consolidation common after open thoracic procedures are virtually abolished, and expansion of the lung is rapid and full usually within 12–24 h, after which the chest drain is removed.

9 Thoracoscopic Sympathectomy and Vagotomy

R. WITTMOSER

Indications

Peripheral Blood Flow Disturbances of the Upper Extremity

The vasomotor fibers for the fingers and hand ascend from the 5th to the 3rd thoracic ganglion in the sympathetic trunk, pass through the stellate ganglion, and join the brachial plexus (Fig. 9.1). The much-practiced extirpation of the stellate ganglion is unnecessary and indeed is contraindicated due to its side effects (Horner's syndrome). Selective endoscopic microsurgical division of the rami communicantes of the 5th, 4th, and 3rd ganglia interrupts the preganglionic vasomotor fibers, which is important for the improvement of long-term results. At the postganglionic level, the long vasomotor fibers in the interganglionic trunk between the 3rd and 2nd sympathetic ganglia can be divided on the 3rd rib.

Hyperhidrosis

Sites of occurrence of hyperhidrosis are highly variable and can range from the head to the plantar surface of the foot (Fig. 9.2). Involvement of the hand and axilla is the most common and severe manifestation. In accordance with the strictly segmental course of the sudomotor fibers, the principal sweat zones can be selectively denervated both in the cervical segments and in the entire thoracoabdominal region as far as the 12th thoracic segment.

Hyperhidrosis of the Head, Face, and Neck. Isolated involvement of these regions is relatively uncommon but very troublesome. Selective division of the rami communicantes of the 2nd thoracic ganglion is sufficient, preferably including the caudal T1 group of rami (Fig. 9.3). An interganglionic section performed on the 2nd rib between T2 and T1 additionally interrupts the postganglionic fibers for the upper extremity.

Hyperhidrosis of the Hand and Arm. The fingers and palm are most strongly affected. Sudomotor denervation is accomplished by the selective preganglionic section of the rami communicantes of the 5th, 4th, and 3rd thoracic ganglia. If only the fingers and hand are affected, the axilla is unaffected, and there is a desire to spare the chest wall zones, the section can be per-

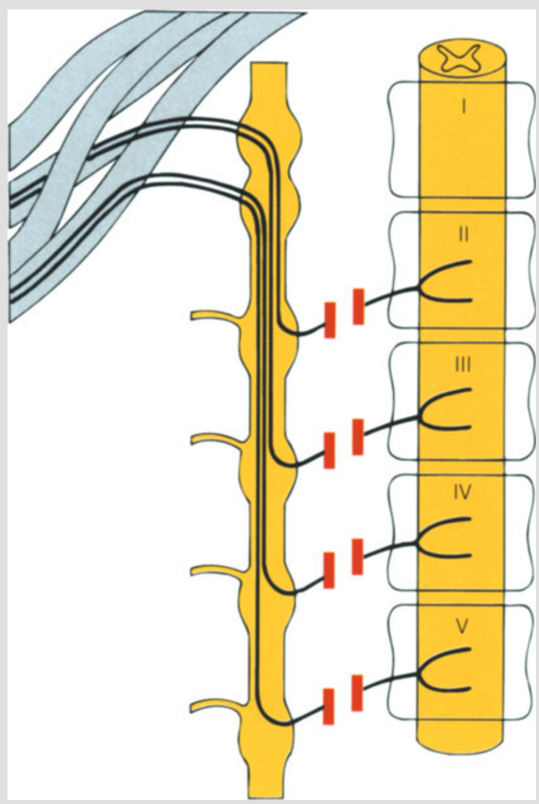


Fig. 9.1. Course of the sympathetic fibers for the fingers, hand, and arm. They pass as long fibers through the rami communicantes of the 2nd or 3rd–5th segments. Rerouted in the associated sympathetic ganglia, they ascend in the sympathetic chain through the interganglionic trunks and pass through the stellate ganglion before joining the brachial plexus. The neurotomy sites are marked in *red*. (Schematic lateral section of the spinal column)

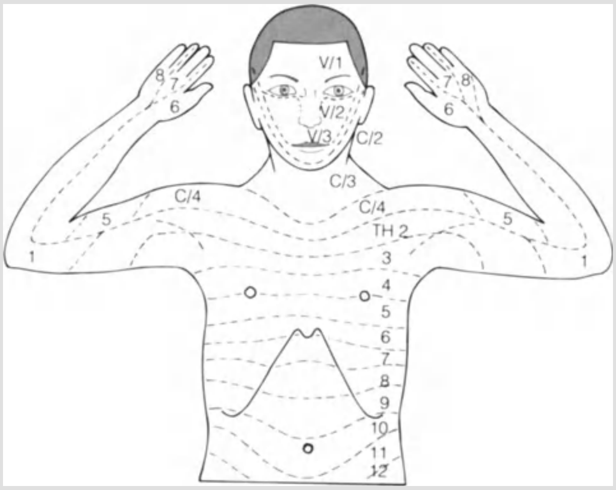


Fig. 9.2. Segmental distribution in the region of the upper quadrants. Due to the ascending course of the sympathetic fibers, a neurotomy at T2/1 also denervates the cervical segments and the trigeminal zones (neck and face). The T4–5 junction is at the nipple level, the T9–10 junction at the level of the umbilicus

formed at the postganglionic level in the interganglionic trunk between T3 and T2 on the 3rd rib.

Axillary Hyperhidrosis. The axilla is a common, usually very troublesome site of occurrence (Fig. 9.4). Because the axillary zone is supplied by short, segmentally arranged sudomotor fibers, only the segmental interruption of the rami communicantes will produce satisfactory results. The axilla is supplied centrally by T3 and caudally by T4; an effective denervation should encompass T2–4.

Truncal Hyperhidrosis. The truncal zones, with their strictly segmental sudomotor innervation, likewise can be denervated only by direct interruption of the rami communicantes. The specific locations of the hyperhidrotic zones are determined preoperatively by a sweat test, and the location of the denervated areas is verified postoperatively. For the frequent involvement of the anterior chest and upper back, the sections cover levels T3 to T8/9; the abdomen and lower back can be denervated at T10–12.

Erythroderma Syndrome

A recurrent flushing of no apparent cause, typically involving the face, ears, forehead, and neck and usually precipitated by contact with other people, is a little-appreciated condition that can be very distressful for the

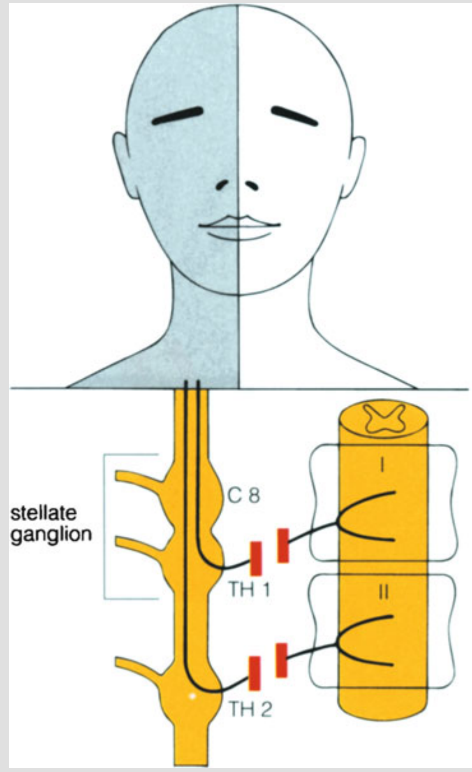


Fig. 9.3. The sympathetic fibers for the craniofacial region pass mainly through the rami communicantes of T2 and possibly the caudal bundles of T1. They ascend longitudinally in the sympathetic trunk and traverse the stellate ganglion and upper cervical ganglia. The neurotomy sites are marked in *red*

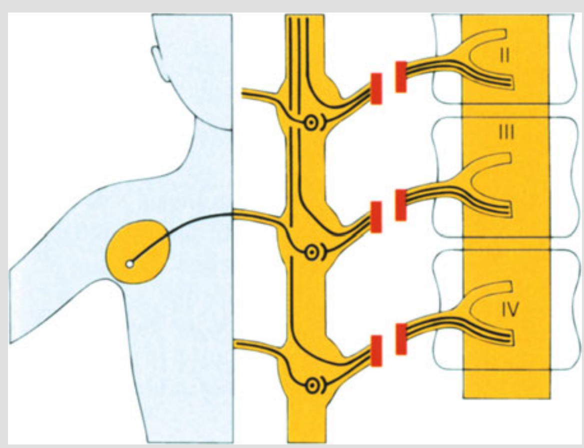


Fig. 9.4. Given the strictly segmental course of the sympathetic fibers for the axilla and trunk, interganglionic nerve sections are unsuccessful; denervation of these zones requires the segmental division of the rami communicantes. The neurotomy sites are marked in *red*

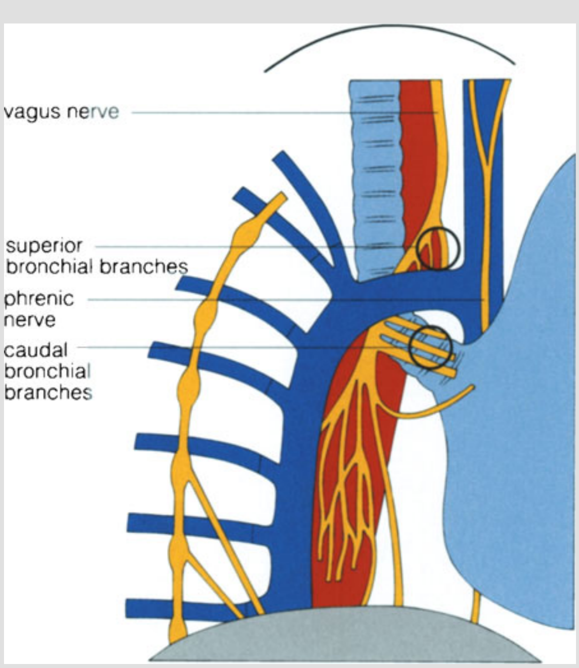


Fig. 9.5. The vagal trunk on the right side passes beneath the azygos arch, giving off superior bronchial branches while still above the arch and the main groups of the bronchial branches just caudal to the arch. A low bronchial branch also may arise from an anterior abdominal trunk. The phrenic nerve courses farther anteriorly on the venous trunk

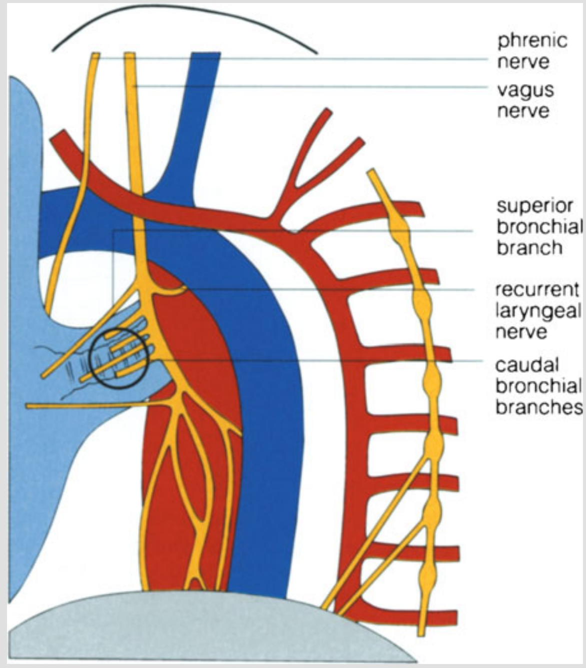


Fig. 9.6. The main vagal trunk on the left side passes over the aortic arch to the hilar region, where the bronchial branches arise anterolaterally in multiple groups. Just above and medial to this site, the recurrent laryngeal nerve winds beneath the aortic arch. The hemiazygos vein usually exhibits a relatively small caliber

patient. This sympathetic dysfunction can be relieved by sectioning the rami communicantes of the 2nd sympathetic ganglion and the caudal group of the 1st sympathetic gangion. Any anastomotic rami that course over the 1st rib should be interrupted as well.

Pain Syndromes

Nocitropic fibers coursing in the sympathetic system contribute significantly to pain symptoms and frequently play a leading pathophysiologic role in patients with causalgia, painful posttraumatic reflex dystrophy, or an upper abdominal pain syndrome.

Sympathicogenic Reflex Dystrophy of the Upper Extremity. This is treated by section of the T3–5 rami communicantes or the interganglionic fibers between T3 and T2.

Pain Syndromes of the Chest Wall. In these syndromes the neurotomy must encompass the segmentally arranged fibers in the rami communicantes of the region between T2/3 and T8/9.

Upper Abdominal Pain Syndromes. These result mainly from certain forms of chronic pancreatitis, rare "postcholecystectomy syndromes" with no pathologic or anatomic substrate, inoperable upper abdominal cancer, intestinal angina, and jejunal peptic ulcer.

Pain conduction for the upper abdominal organs is mediated by the splanchnic nerves. For the stomach and gallbladder, it is sufficient to section the T5/6–8 splanchnic roots; for the pancreas, the rhizotomy should extend to T11.

Bronchial Asthma

Selective division of the bronchial rami of the vagus nerve (Fig. 9.5) can improve or relieve bronchospasm (confirmed in animal experiments for various bronchoconstrictor stimuli; Ulmer et al. 1982). As we showed in the 1950s, selective vagotomy can be performed thoracoscopically at a site caudal to the azygos arch on the right side (Fig. 9.5), and caudal to the aortic arch in the region of the pulmonary hilum on the left side (Fig. 9.6). It is not necessary to add a sympathectomy for the bronchial region.

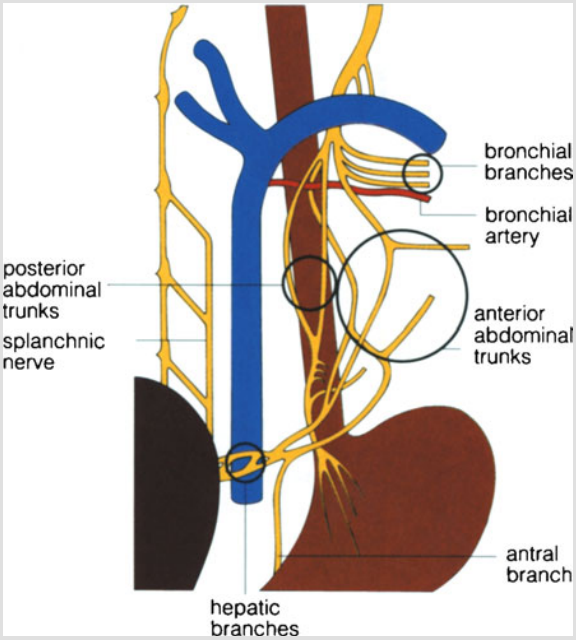


Fig. 9.7. Division of the right vagus nerve into posterior abdominal trunks, which are distributed to the gastric fundus and corpus, and anterior abdominal trunks, which mainly supply the antrum and the liver

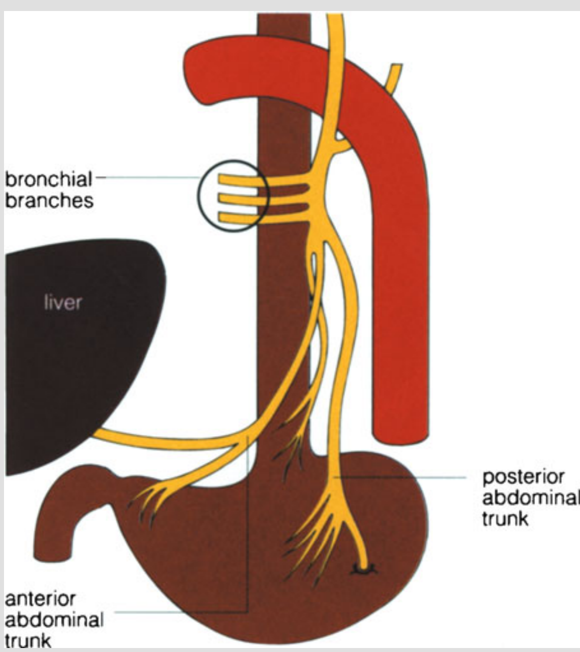


Fig. 9.8. Division of the left vagus nerve into posterior abdominal trunks, which supply the gastric fundus and corpus, and anterior abdominal trunks, which chiefly supply the antrum and the liver

Peptic Ulcer Disease

Thoracoscopic division of the abdominal vagal nerve trunks has become the procedure of choice for the treatment of jejunal peptic ulcer (Fig. 9.7, 9.8). We always add a splanchnicotomy at T5/6–8. Primary duodenal peptic ulcer can be treated by semiselective thoracoscopic sections of the posterior abdominal trunks, likewise combined with splanchnicotomies for the gastroduodenal region (see above).

Angina Pectoris

Minimally invasive surgery is particularly important in the case of the heart when it replaces, say, a bypass operation. Expecially as an adjunct to intraluminal coronary interventions, endoscopic neurotomy continues to be an important procedure for the permanent, selective autonomic protection of the heart.

The cardiac branches of the sympathetic trunk and vagus nerve are easily accessible to thoracoscopy in the region of the pleural apex, (Fig. 9.9) and the aortic

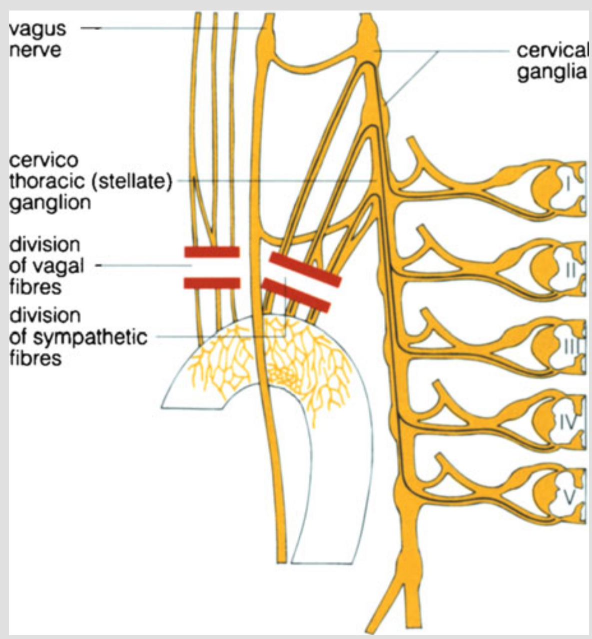


Fig. 9.9. Pain fibers ascending from the heart via the cardiac-aortic plexus and the cardiac nerves of the sympathetic system pass through the sympathetic cervical ganglia but then descend again in the sympathetic trunk before entering the spinal cord segmentally between T1 and T5. Thus, these fibers can be cut thoracoscopically at the interganglionic level in the upper sympathetic cord or within the rami communicantes. The cardiac branches of the vagus nerve run anterolateral to the main vagal trunk in the apical region

plexus is easily accessible on the aortic arch (Wittmoser 1963).

Instrumentation

The thoracoscopic surgery of pleural adhesions began in the 1920s and 1930s using a *multipuncture technique* in which the telescope, distal light source (small, low-voltage bulb), and operating instruments were passed into the thoracic cavity through various puncture sites. For the more precise thoracoscopic surgery of the autonomic nerves using optical magnification, we have always preferred a *single-puncture technique* in which the operating instruments are automatically kept within the visual field of a 0° telescope and within the congruent illuminating beam. This avoids the coordination problems of the multipuncture technique.

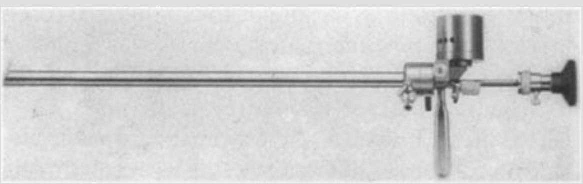
The first gas-tight operating thoracoscope with multiple operating channels and a proximal light source (quartz rods) was produced in 1959 from a design that we developed in collaboration with Storz (Fig. 9.10).

The gas-tight seal and pressure-regulated CO_2 delivery (developed in 1957) allowed for precision surgery even under difficult intrathoracic pressure conditions (e.g., in bronchial asthma patients) (Chap. 2, Fig. 2.9 a).

Air-lens systems (Hopkins) and fiberoptic light cables, in use since 1965, reduce the diameter of the telescope, making it possible to enlarge the operating channels to the current standard (Fig. 9.11).

Operating endoscopes with a retractable telescope (in use since 1975) provide full-circumference protection of the operating space at the end of the sheath (Fig. 9.12). This permits endoscopic dissection under vision in any soft tissue environment, i.e., during perforation of the chest wall or abdominal wall.

Our oblique telescope (introduced in 1973) permits the introduction of rigid, relatively large-caliber instruments (bipolar forceps, clip placers, ultrasound



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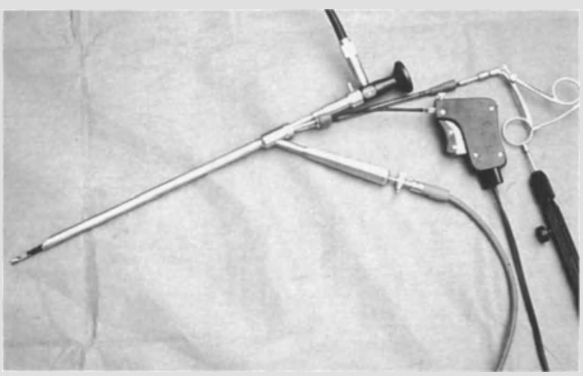


9.11 a

b

Fig. 9.10. Our first gas-tight operating thoracoscope (1959) with multiple operating channels. Light from the proximal incandescent bulb is concentrated by a concave mirror and transmitted through a quartz rod

Fig. 9.11. **a** Modern operating endoscope with retractable telescope and multiple instrument channels. **b** Tip of the operating endoscope with dissecting hook, suction, and coagulation electrode

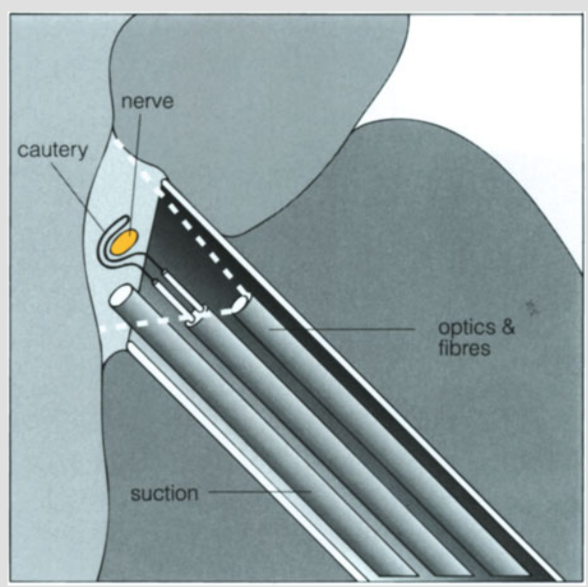


Fig. 9.12. Principle of tube dissection. With the telescope retracted, the end of the sheath provides a circumferentially shielded space for tissue dissection

probes, photocoagulators, etc.) through a straight operating channel (Fig. 9.13) and is currently used in almost all endoscopic disciplines.

The flexible optical adapter ("accordion optic"), designed by us in 1968 (Fig. 9.14), employs a system of prisms and lenses that can transmit the endoscopic image without significant loss of resolution or color quality from the eyepiece to a large three-tube video camera while preserving the intraoperative mobility of the endoscope. Since the development of mini-video cameras that couple directly to the endoscopic eyepiece, the adapter can now be used as a high-quality viewing device for observers.

The low-frequency electrocautery with a Dechamps-type curved platinum-iridium loop (Fig. 9.15) is ideally suited for the microsurgical dissection of fine structures, sectioning and concomitant hemostasis, and for the division of massive cordlike or membranous pleural adhesions. A flexible model 3 mm in diameter is available for curved operating channels, and a thicker, rigid version is availble for straight channels. The instrument works by heating of the wire loop, with no flow of electric current through the tissue.

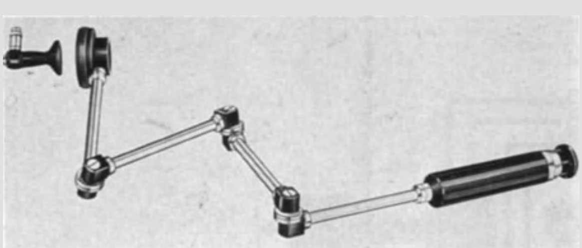
Unipolar high-frequency forceps with appropriate insulation are part of the standard equipment for hemostasis.

Bipolar forceps have been our preferred instrument since 1970 because they are safe to use on smaller bleeding points.

Thermostabilized bipolar forceps (Fig. 9.16) are the least hazardous coagulation instrument currently available but require a special control device (Fig. 9.17).

Light-contact coagulation probes are easy to use but provide a limited depth of coagulation.

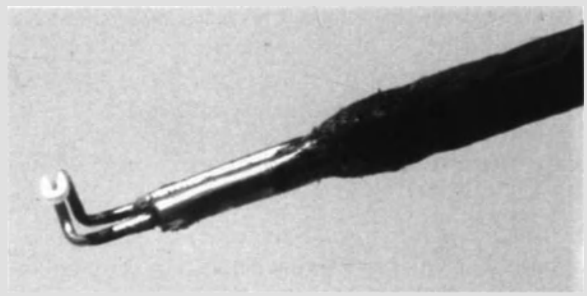
9.13



9.14

Fig. 9.13. Our oblique-viewing endoscopic telescope permits the insertion of rigid, larger-caliber operating instruments

Fig. 9.14. Our flexible optical adapter can transmit the endoscopic image to a heavy camera or can permit viewing by an assistant



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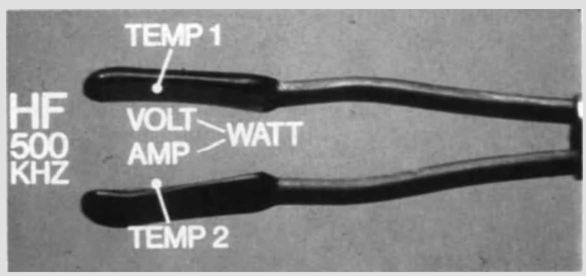


9.16

9.17

Fig. 9.15. Low-frequency platinum-iridium electrocautery with Dechamps-type curved cutting loop

Fig. 9.16. Forceps for thermostabilized bipolar coagulation

Fig. 9.17. Standard HF 400-watt power unit *(top)* with auxiliary integration unit and low-voltage LF generator *(bottom)*

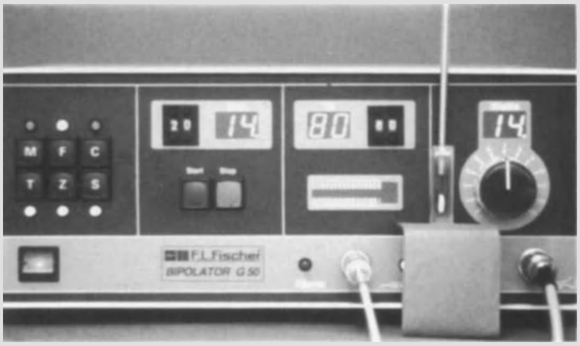


Fig. 9.18. Generator for thermostabilized bipolar HF coagulation. The coagulation time *(left)* and coagulation temperature *(center)* can be preset and are displayed by continuous digital readouts. The power in watts *(right)* is microcontroller-regulated when the unit is in the automatic operating mode (circuit diagram, Fig. 9.19)

Fig. 9.20. A CO_2 insufflation unit with preset, electronically controlled insufflation pressure and dual electronic pressure limiter. Digital display of intracavitary pressure and flow (and of total filling volume). Touch switches are used to preset and adjust the parameters

Equipment for Thoracoscopy

A standard high-frequency unit with a maximum power output of 300–400 W is needed mainly for unipolar forceps coagulation. The unit can also supply *bipolar* forceps or probes (up to about 50 W).

An auxiliary integration unit (Fig. 9.17) contains a *low-voltage low-frequency generator* to power the low-frequency (LF) cautery (with platinum-iridium loop), which we prefer over the high-frequency (HF) cautery for dissection and cutting, and an integration circuit that permits the operator to switch from the HF to the LF cautery at any time by pressure on a footswitch.

A generator for thermostabilized bipolar HF coagulation permits coagulation at a constant preset temperature using special probes and forceps (Figs. 9.18, 9.19).

A CO_2 insufflation unit enables the insufflation pressure to be preset and electronically maintained at a constant level. The current filling pressure, intracavitary pressure, and flow are indicated on digital displays (Fig. 9.20).

Suction devices feature a selector switch and pressure limiter to protect the lung tissue, with volumetric monitoring (e. g., at 500 ml) to ensure that significant blood volumes are not missed and with digital negative pressure readout. Roller pumps of adequate capacity are also suitable.

An Infrared generator allows photocoagulation.

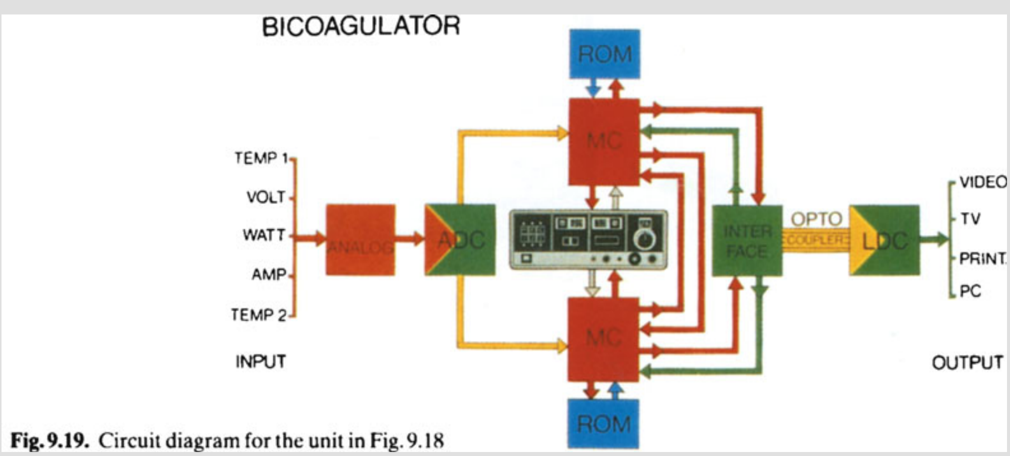


Fig. 9.19. Circuit diagram for the unit in Fig. 9.18

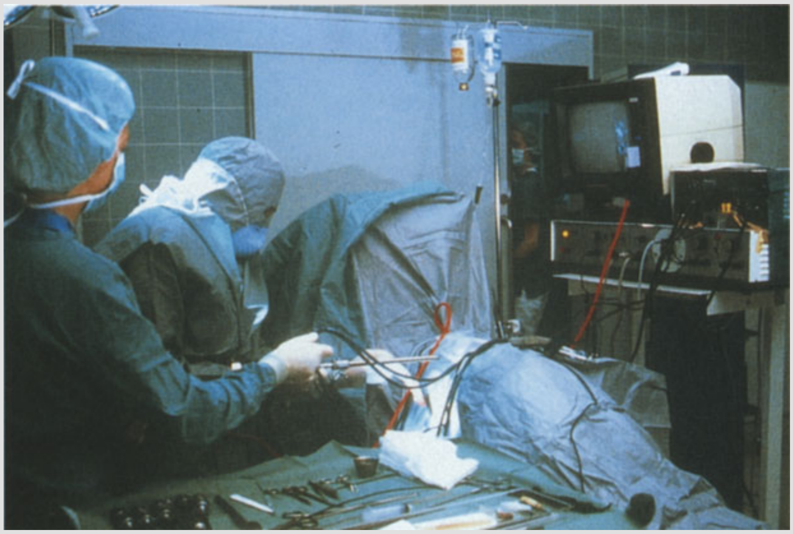


Fig. 9.21. Setup for left-sided thoracoscopy using a parascapular approach to the 5th ICS. Video recording endoscopy (video cable shown in *red*)

Positioning

The *prone position* affords the best access to the sympathetic chain and vagus nerve branches, because the lung falls forward under the force of gravity, giving free access to the spine and mediastinum.

The patient's *head* lies on a kidney-shaped rest of adjustable width that supports the forehead while leaving the eyes, nose, and mouth exposed. This provides unobstructed access for intubation anesthesia.

The *upper arm on the operated side* hangs freely, while the forearm is suspended in a sling with the elbow flexed 90°. This position draws the scapula away from the spine to provide a favorable access angle for endoscope insertion.

The *contralateral arm* rests on a transfusion board with the shoulder and elbow joints in an intermediate position.

The *pelvis* is elevated to permit unrestricted abdominal respiratory excursions.

The video equipment and auxiliary devices are placed at the head of the operating table (Fig. 9.21).

Incision

We find that a single incision is generally adequate. A 10- to 12-mm oblique incision in the 5th intercostal space (ICS) at the medial scapular border, 12–15 cm from the midsagittal line, usually affords good access to the entire thoracic sympathetic trunk and the vagus nerve branches (Fig. 9.22).

For sympathectomies of the more cranial segments – T1–T3/4 – it is better to enter within the 4th ICS directly at the scapular border. For dissection of the caudal sympathetic segments – T10–T12 – we prefer entering in the 7th or 8th ICS at the same paravertebral distance.

Approach through the 6th ICS is most favorable for vagus nerve dissection caudal to the azygos arch.

For sympathetic nerve dissections in the apical region and costophrenic recess, one portal can be established in the 4th ICS and a second portal in the 8th ICS.

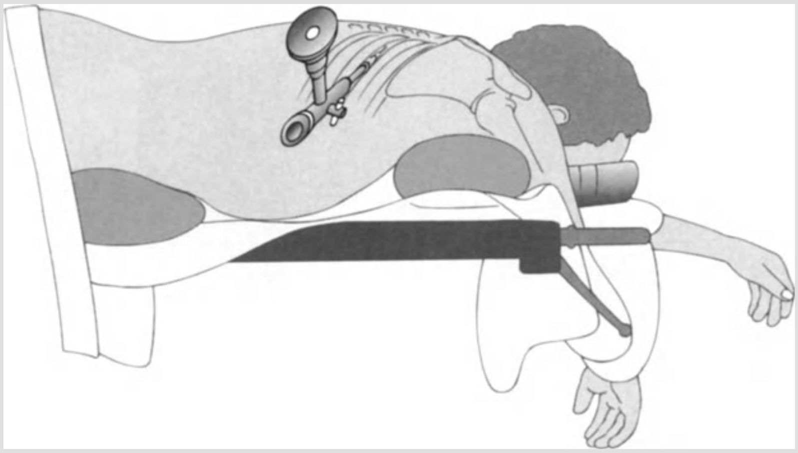


Fig. 9.22. Prone position for a right-sided thoracoscopic sympathicotomy or vagotomy. The pelvis and shoulder are elevated. The arm on the operated side hangs downward while the opposite arm rests on an infusion board. The head is supported on a contoured, adjustable rest

Operating Technique

The Anatomy of the Sympathetic Nervous System (Figs. 9.5, 9.6)

The sympathetic trunk courses over the heads of the ribs and is usually visible through the pleura (Fig. 9.23). Obesity or scarring of the pleura can however, obscure the sympathetic trunk, which then must be exposed by sharp dissection of the pleura at the heads of the ribs.

The sympathetic ganglia are located in the intercostal spaces or, less commonly, on the associated caudal rib.

The interganglionic trunks course between the ganglia over the corresponding ribs and often are clearly visible and palpable using the cold LF cautery as a probing instrument.

The rami communicantes arise at the dorsal border of the typically triangular ganglion (Fig. 9.24). The main trunk of the gray rami, which joins the intercostal nerve, is frequently visible through the pleura. The white rami course in a deeper layer (viewed from the pleura), behind or medial to the ganglion, and emerge from the spinal cord roots (Fig. 9.25).

The visceral rami arise ventrally from the sympathetic ganglia. The cardiac and pulmonary rami are faintly visible beneath the pleura.

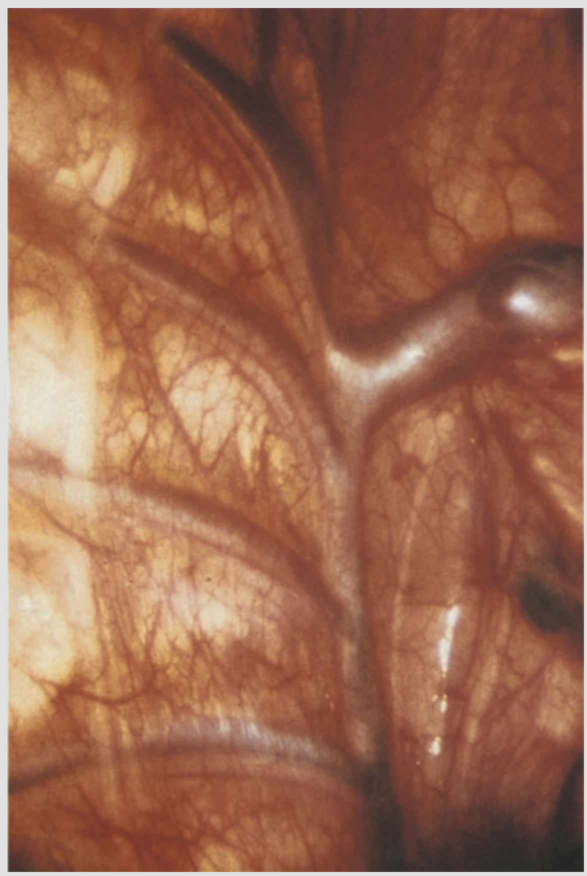


Fig. 9.23. Right thoracic cavity with the azygos venous tributaries and azygos arch. At left is the sympathetic trunk, which courses on the heads of the ribs and is visible through the pleura. Below the azygos arch are the abdominal trunks of the vagus nerve on the esophagus. Above the azygos arch, the main vagal trunk is visible through the pleura. The pulmonary hilum (sectioned) is shown at right

Fig. 9.24. Right thoracic cavity, 4th and 5th segments. Dorsally (at left) the main bundles of the rami communicantes arise from the dorsal ganglion border near the intercostal vessels, where they are clearly visible through the pleura, which is largely devoid of fat

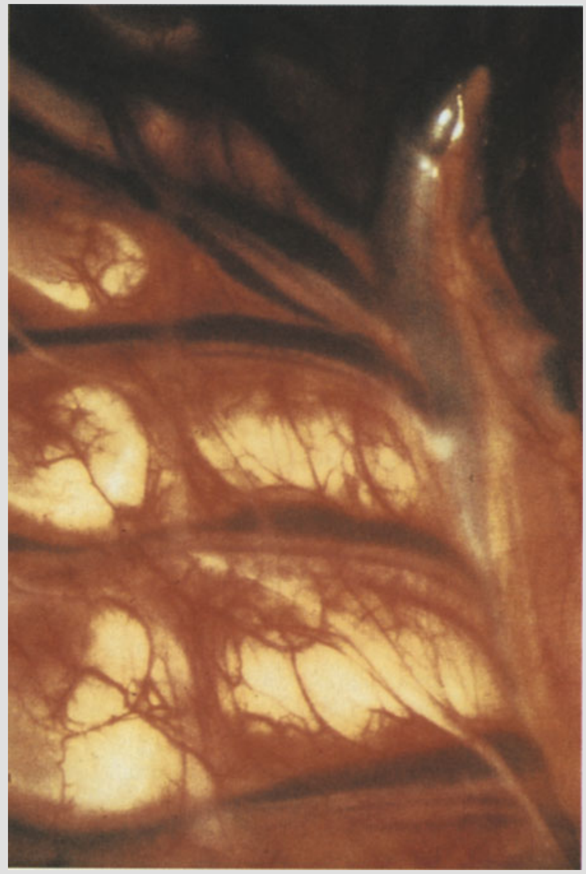


Fig. 9.26. In the lower third of the picture is the first large splanchnic root, which arises from the 6th thoracic segment and descends behind (left) the esophagus and azygos vein to enter the main trunk of the splanchnic nerve. The lung appears at right, and at the top of the picture is the azygos vein inflow tract and the azygos arch

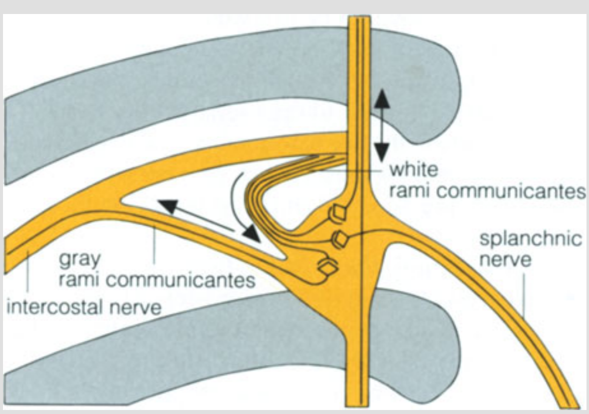


Fig. 9.25. Diagram of the gray and white rami communicantes at the dorsal ganglion border *(left)* and of a splanchnic nerve root *(right)*

The splanchnic roots, especially the main root, which usually arises from T6, are frequently visible and palpable beneath the parietal pleura (Fig. 9.26). Passing obliquely forward and downward, the roots of T6–T8 unite in the trunk of the greater splanchnic nerve, while the more caudal roots unite in the trunk of the lesser splanchnic nerve.

On the right side the main splanchnic nerve trunks run dorsal and parallel to the azygos vein. In this region the thoracic duct also courses between the esophagus and azygos vein into the subpleural space; aberrant branches may be in direct proximity to the splanchnic nerves. *On the left side* the splanchnic nerves run just dorsal to the hemiazygos vein. This region is generally devoid of large lymphatic trunks.

Sympathectomies

T1–3 Sympathectomy. The fibers for the face and neck (erythroderma, hyperhidrosis, pain syndromes) are accessible at T2.

Creation of a Pleural Window. The subpleural course of the nerve is visualized with the operating thoracoscope (Fig. 9.31 a). A Deschamps-type dissection hook is passed beneath the pleura to elevate it from the nerve (Fig. 9.31 b). The LF cautery is activated by hand switch to heat the hook (without passing current through the tissue) and divide the elevated tissue (Fig. 9.31 c). This creates a pleural window through which the exposed nerve can be picked up on the hook, isolated by blunt dissection (Fig. 9.31 d, e), and divided by activation of the hook.

Extension of the Pleural Window. The window is first extended inferiorly into the 2nd ICS past the sympathetic ganglion while the parietal pleura is elevated from the nerves and blood vessels. Safety is further increased by CO_2 insufflation (at about 20 mbar) into the subpleural space.

The pleura is incised over the ganglion for several millimeters dorsally until the ganglion, usually triangular in shape, is exposed at the base of the pleural window (Fig. 9.27).

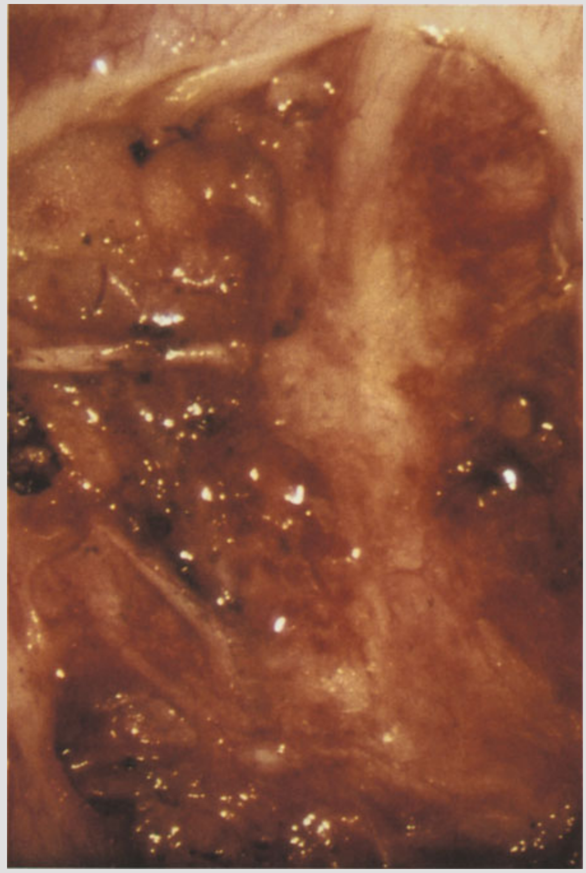


Fig. 9.27. Sympathetic ganglion dissected in a pleural window. The main bundle of the gray rami communicantes is given off upward (dorsally); the interganglionic trunks pass to the right and left

Dissection of the Rami Communicantes at the Dorsal border of the T2 Ganglion. The superficial main bundle of the *gray rami,* which lies just beneath the pleura, is picked up on the LF cautery loop and electrically served.

The deeper *white rami* are picked up on the LF cautery loop, which is bent back slightly, starting from the 2nd rib and proceeding caudad along the dorsal border of the interganglionic trunk. The rami are elevated away from the underlying vessels and divided. The dissection is performed under optical magnification to ensure completeness and is continued past the caudal border of the ganglion, which should then be freely mobile.

T1 Partial Communicating Ramicotomy. The first thoracic ganglion joins with the 8th cervical ganglion to form the stellate ganglion, whose extirpation or disruption leads to a complete Horner's syndrome with severe narrowing of the palpebral fissure and pupillary constriction. Because the sudomotor and vasomotor fibers for the craniofacial region ascend largely from T2 and only pass through the stellate ganglion in their centripetal course, an open stellectomy is contraindicated. Since several such centripetal fibers may be present in the caudal fascicles of the T1 rami communicantes, they also should be cut in suitably selected cases (see above): A pleural window is placed at the cranial border of the 2nd rib, extending 10–15 mm dorsally from the interganglionic trunk. The dissection is carried upward to the caudal border of the T1 ganglion, where the two to four most caudal bundles of the rami communicantes, which pass dorsally toward the 2nd rib, are dissected and coagulated (Fig. 9.28).

T1–2 Anastomotic Ramicotomy. In approximately two thirds of cases the 2nd rib is crossed dorsal to the interganglionic trunk by one to three fine branches that pass from the 1st to the 2nd intercostal space (Kuntz's fibers) and establish a neurophysiologic shunt. Adding the division of these rami ensures complete autonomic denervation of the face and neck region: A pleural window is made dorsally from the head of the

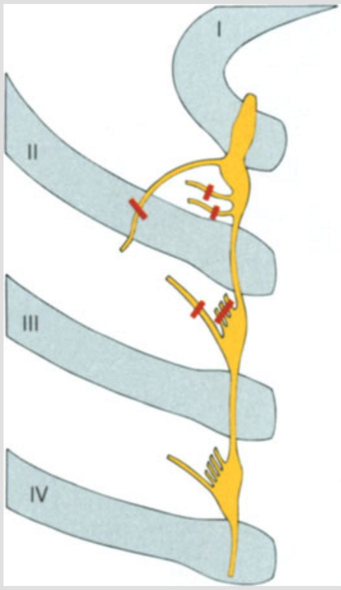


Fig. 9.28. Besides the rami communicantes in the 2nd ICS, two caudal bundles of rami communicantes from T1 and an anastomotic ramus between the 1st and 2nd ICS have been divided

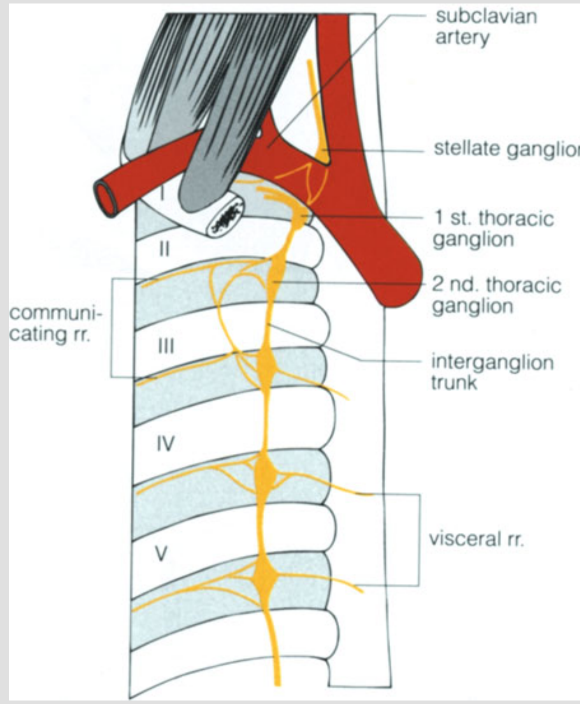


Fig. 9.29. Rami communicantes of the 3rd to 5th segments: anatomic appearance

2nd rib. Usually the anastomotic rami are plainly visible in the pleural window and can be picked up on the LF cautery loop and divided. It is also sufficient to coagulate a strip of pleura against the costal periosteum.

Dissection of the T3 Ganglion. Just as at T2, a pleural window is created over the ganglion, and the rami communicantes are dissected. Complete division of the rami is particularly important in axillary hyperhidrosis because the axilla is supplied mainly by segmental sudomotor fibers from T3. Although coagulation of the gray rami should be adequate in theory, we also recommend cutting the deeper white rami while giving attention to fine anteromedial fibers; this avoids the residua and recurrences that are particularly common at the T3 level (T3 syndrome). Additional coagulation of the T2 and T4 gray rami ensures a good result for axillary hyperhidrosis.

Fig. 9.30. Sweat test to evaluate the success of the sympathicotomy. The effect of denervating the upper right quadrant is indicated by the light coloration

T3–T5 Sympathectomy

The preganglionic sympathetic fibers for the hand and arm course in the white rami communicantes of the 5th segment (Fig. 9.29) where, as at T2 (see next paragraph), they can be segmentally dissected and divided before they ascend as long fibers via the interganglionic trunks to the stellate ganglion and brachial plexus. This can ameliorate acral blood flow disturbances as well as hyperhidrosis of the hand and arm. Access in the 3rd–5th ICS is gained through pleural windows several millimeters in diameter over the sympathetic ganglia. These sections also interrupt the sudomotor fibers in the gray rami for the axilla and chest wall as for as the nipple line (T5–6 junction, Fig. 9.30).

The Perspiration Test. This test is used to help determine whether sympathectomy is indicated and to

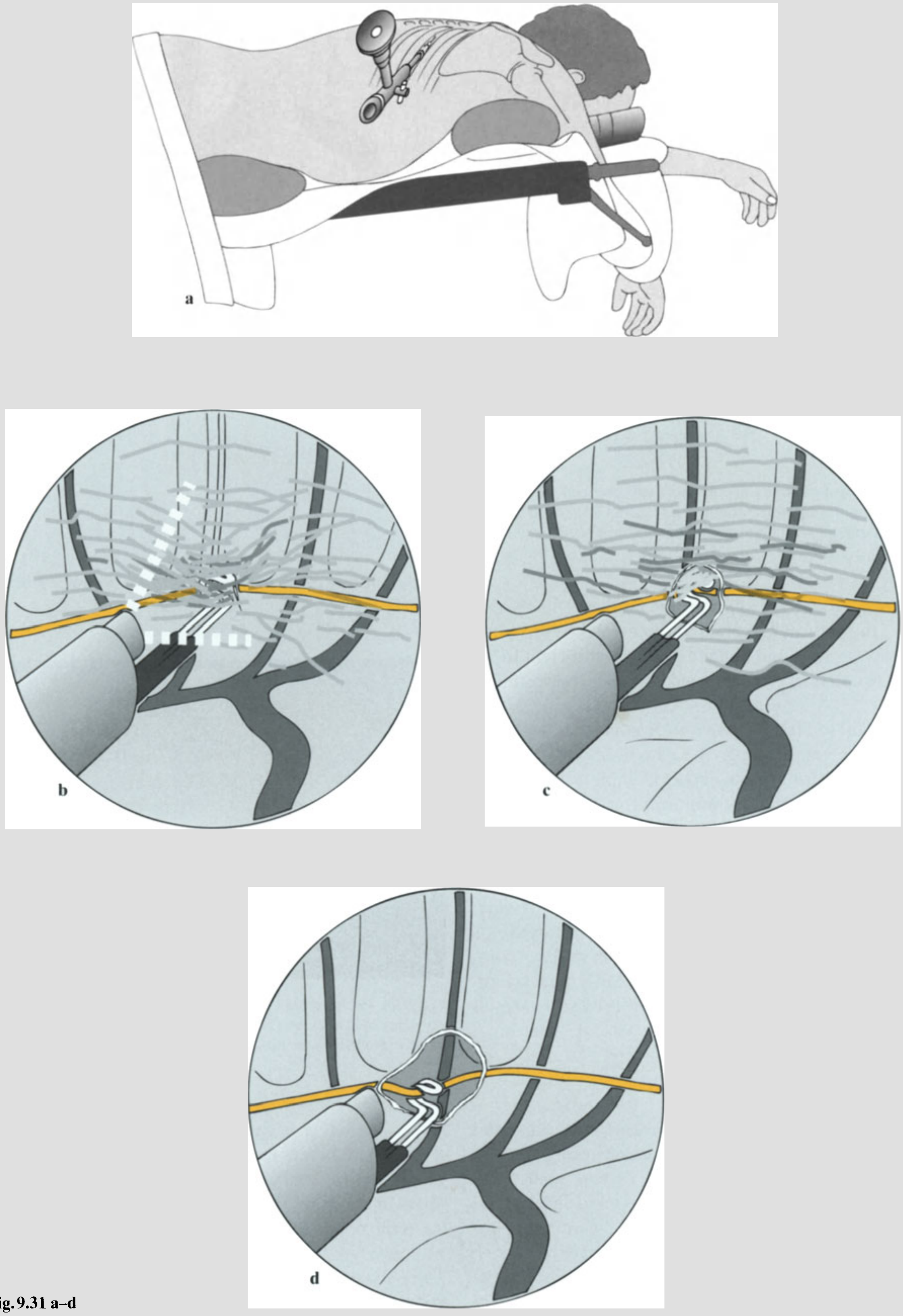
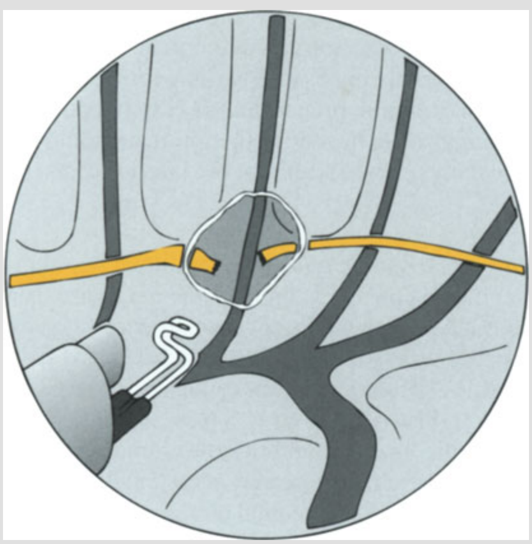


Fig. 9.31 a–d

e



f

Fig. 9.31. **a** The position of the operating mediastinoscope with respect to the operative field. The subpleural course of the nerve is demonstrated. **b** The pleura is bluntly engaged with the Deschamps-type dissection hook and elevated from the nerve and surrounding chest wall. **c** Activating the LF current heats the hook and divides the pleura. **d** The nerve is picked up on the hook and bluntly dissected along its course. **e** Endoscopic appearance of the nerve on the hook. The large interganglionic trunk at the border of the 3rd right thoracic ganglion can be picked up on the cautery loop and safely divided. **f** Nerve after division

check the result. An iodine-oil-starch emulsion [composition: iodine 3.0, ether 34.0, corn starch (dried at 60° for 24 h) 45.0, castor oil 68.0] is applied to the skin. When the patient perspires the light-brown solution turns blue-black. After sympathectomy the denervated area remains completely light brown or exhibits isolated spots of discoloration, while sudoriparous areas turn blue-black. The results are recorded in a standardized series of colour photographs.

Procedure

- The patient drinks 1 l warm tea with 1 g acetylsalicylic acid.
- The emulsion is applied using a wide brush.
- The patient is covered with a heating frame and a blanket.
- The temperature is raised to 60° and maintained until the effect is achieved (average 35 min).

T3 Interganglionic Sympathectomy

The pleura is windowed on the head of the 3rd rib and thus between the 2nd and 3rd sympathetic ganglia. The interganglionic trunk is usually visible or at least palpable at this level and can be picked up on a cautery loop and safely divided by switching on the current (pistol grip) (Fig. 9.31). After division and dissection of the perisympathetic tissue, the stumps will retract and can be buried beneath the edges of the pleural window as a precaution against reinnervation.

The interganglionic sympathectomy at T3 interrupts the long fibers for the fingers and hand, though at the postganglionic level. An *interganglionic section at T4* can be added to prevent recurrence.

T2 Interganglionic Sympathectomy

Interganglionic sympathectomy at T2, between the 2nd and 1st thoracic ganglia, interrupts the long fibers for the face, head, and neck. The pleural window is placed at the head of the 2nd rib, and the interganglionic trunk, which usually is on the ventral aspect of the head of the rib, is carefully identified, picked up on the cautery loop, and divided. Confusion with fiber bundles of anterior langitudinal muscle (longus colli) must be avoided. A large vascular bundle may cross the 2nd rib dorsally near the interganglionic trunk and may run closely adjacent to an anastomotic sympathetic branch (see above, T1–2 Anastomotic Ramicotomy).

Because an interganglionic syr
interrupts the fibers for the finger

addition to the fibers for the face, head, and neck, the indication is generally limited to cases where there are corresponding sites of hyperhidrotic involvement and the axilla and chest wall are to be spared. Other cases are better managed by selective division of the rami communicantes (see above, T3 Interganglionic Sympathectomy).

T6–T12 Sympathectomy

The trunk wall in this region is innervated mainly by short segmental sympathetic fibers that can be interrupted only within the rami communicantes at the dorsal ganglion border (for treatment of truncal hyperhidrosis, thoracic pain syndromes).

"Normal" anastomic conditions tend to prevail at the *6th–9th sympathetic ganglia* (Fig. 9.32), so a standard pleural window is placed over the ganglion. The gray rami that pass to the trunk wall usually arise in a large bundle from the tapering dorsal ganglion border, where they can be superselectively isolated and coagulated or sectioned (see above, T1–3 Sympathectomy). The deeper bundles of white rami also are isolated from the intercostal vessels and divided to prevent reinnervation.

Anatomic variants of the sympathetic trunk are common *at the 10th–12th sympathetic ganglia,* e.g., the trunk may deviate dorsally between T9 and T10 and then resume a more ventral course toward the spinal column at T11 and T12. In obese patients this region may be obscured by lipomatous tissue that must be removed. The dissection follows the course of the interganglionic trunks, which tend to be much thinner in this area than in the cranial segments as the pleura over them is incised from ganglion to ganglion. The pleura over the ganglia is further incised a few millimeters dorsalward until the ganglion is exposed. After identifying the anatomic relationships, the surgeon proceeds with dissection of the rami communicantes at the dorsal ganglion border in standard fashion (see above).

For exposure of the T12 ganglion and usually T11 as well, the reflection of the costophrenic recess must be incised and the retropleural supraphrenic space opened. From there the subphrenic retroperitoneal space is entered by tracing the interganglionic trunk between T12 and L1 through the diaphragm.

Interganglionic Sympathectomies at T9–12

Interganglionic sympathectomies at T9–12 may have to be added (see above, T3 Interganglionic Sympathectomy), since longer descending sympathetic fibers in these segments usually contribute to the innervation of the trunk wall. The denervation can be extended into the pubic and inguinal region by thoracoscopic interganglionic sympathectomy in the region of the T12–L1 interganglionic trunk (a bilateral procedure in males may cause retrograde ejaculation).

Anatomic Variations

Anatomic variations of the sympathetic trunk and in the course of the intercostal vessels can complicate dissection of the sympathetic branches.

Anastomotic rami between the 1st and 2nd ICS may be absent or multiple. Usually one to three fine branches cross the 2nd rib dorsal to the T1–2 interganglionic trunk (see above, T1–2 Anastomotic Ramicotomy) and a vascular bundle. An anastomotic ramus may closely overlie the dorsal or ventral aspect of the vascular bundle, in which case it must be bluntly freed with the curved cautery loop, isolated, and divided. There is usually a space several millimeters wide between an anastomosing vascular bundle and the interganglionic trunk; this space also may contain a sympathetic anastomotic branch that is closely apposed to the cranial costal border of the interganglionic trunk and first enters the 2nd ICS at the inferior costal margin.

Anastomotic rami in other segments are less common, either passing obliquely upward and backward from a caudal ICS into the adjacent cranial space (e.g., from T4 to T3) or descending obliquely backward from a cranial ICS into the adjacent caudal space (e.g., from T2 to T3). In rare cases an ICS (e.g., T3) may receive anastomotic inflow from both the cranial and caudal sides, in which cases there may occasionally be no separate ganglion with segmental rami communicantes.

The location of the sympathetic ganglion in the ICS is variable. Not infrequently, the ganglion deviates from its typical "central" position between the heads of adjacent ribs and may be as low as the associated caudal rib, possibly even extending into the next ICS. In this case the segmental ICS does not contain a ganglion but only a long interganglionic trunk, which may be markedly thin. A low-sited ganglion is not uncommon when large vessels overlie the sympathetic trunk in the

ICS (see next paragraph). In other respects, however, the segmental arrangement of the sympathetic system is so regular that selective neurotomies can be performed with a high degree of accuracy, as postoperative sweat tests can affirm (Fig. 9.30). Earlier concepts of a highly variable anastomotic network have not been confirmed.

Variations in the course of the intercostal vessels are also observed. The sympathetic trunk generally lies directly beneath the parietal pleura, the intercostal vessels coursing medial to it (or behind it as viewed from the pleural cavity). A large vein or venous bifurcation may "overlie" the sympathetic trunk, however, coming between it and the pleura.

In these cases the ganglion is often displaced onto the associated caudal rib, so that the rami communicantes can be retracted downward from the vein and safely coagulated. If the ganglion is directly covered by the vein, the vessel is completely undermined on the cranial and caudal sides so that the rami can be picked up and divided.

Less commonly an intercostal artery passes over the ganglion or an arterial bifurcation passes close beneath it, and the intercostal artery of the cranially adjacent ICS may be apposed to the sympathetic trunk. This can lead to hemorrhage or cause confusion between a contracted artery and the interganglionic trunk. With benefit of optical magnification, the arterial branches can be separated from the sympathetic trunk and will not seriously hamper access to the rami communicantes and interganglionic trunks.

Deviations in the course of the vessels are most common in the 2nd through 4th segments.

Splanchnicotomies

T5/6–8 Splanchnicotomy

The branches arising at T5/6–8 mostly supply the stomach and duodenum. The highest, usually best-developed splanchnic root most commonly arises at T6 but may originate at T5 or T7.

The main root is exposed in its obliquely forward descending course on the spinal column in the region of the next lower intervertebral disc (Figs. 9.26, 9.32) ventral to the sympathetic trunk using a pleural window several millimeters in diameter. This is a largely avascular zone near the crossing of the intercostal vessels, which usually is clearly visible. The splanchnic root is picked up on the curved cautery loop, pulled

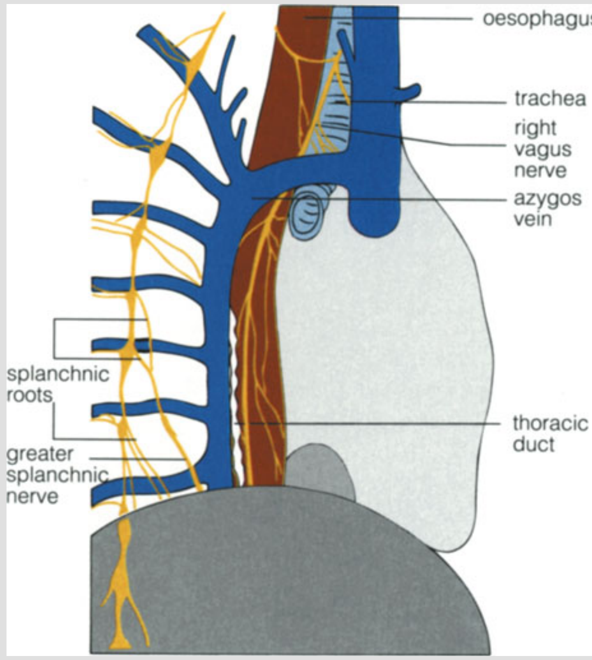


Fig. 9.32. Right sympathetic trunk with origins of the splanchnic root and the azygos system. Course of the vagus nerve on the esophagus. The thoracic duct at the border of the azygos vein may give off branches that closely approach the splanchnic roots

away from the spine, and divided (Fig. 9.33). After dissection of the loose perisympathetic connective tissue, the stumps will retract several millimeters and can be buried beneath the pleural margins. When the root arises from the 6th sympathetic ganglion, it is divided between the 7th and 8th segment due to its obliquely descending course.

Splanchnic roots (usually small) arising from the 7th and 8th sympathetic ganglia likewise take an obliquely forward descending course before converging on the trunk of the greater splanchnic nerve. These splanchnic roots, which are variable in size and number between T5 and T8 (usually numbering 2–4), are individually exposed and divided through small pleural windows one segment caudal to their origin on the spine.

The main trunk of the greater splanchnic nerve is sought at T9/10 on the spinal column, distal to the afferents from the T5–8 roots. The splanchnic trunk runs just dorsal to the azygos vein (right) or hemiazygos vein (left). It must be isolated from the vein in its pleural window and dissected completely "naked" by blunt dissection (especially on the right side) to avoid injury to thoracic duct branches. These branches are difficult

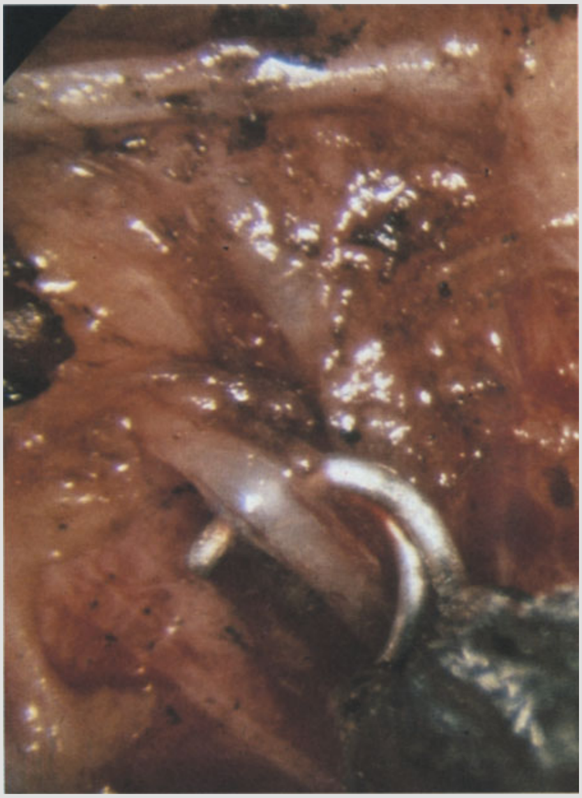


Fig. 9.33. Main root of the splanchnic nerve of T6, dissected and elevated in its course on the 7th thoracic vertebra (patient in prone position)

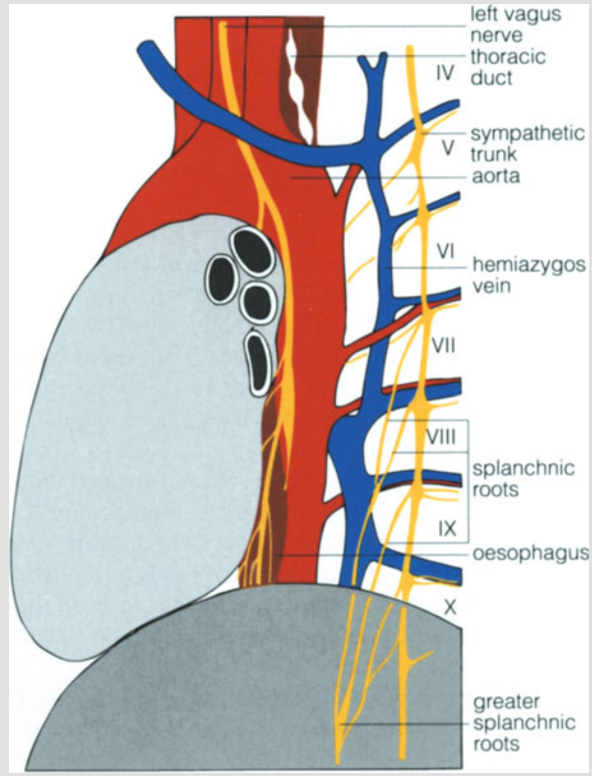


Fig. 9.34. Left sympathetic trunk with splanchnic roots and hemiazygos system. Termination of the thoracic duct in the apical region. Thus vagus crosses the aortic arch and passes over the pulmonary hilum to the esophagus

to identify by dissection and, on the *right* side, may be closely apposed to the greater splanchnic nerve. Their injury leads to a chylothorax that will require treatment.

There is no comparable danger of chylothorax on the *left* side, but the bloodless hemiazygos vein may be confused with the splanchnic trunk in its course through the frequently abundant subpleural connective tissue and fat; profuse hemorrhage results if this vein is severed (Fig. 9.34).

Having been largely isolated from the adjacent tissues, the *splanchnic trunk* is finally picked up on the curved LF cautery loop, brought through the pleural window, carefully reidentified (compressibility, distensibility, surface structure, glossiness), and electrically divided (pistol grip switch).

The stumps, which display an engorged, gleaming white cross section, are mobilized somewhat further and buried beneath the edges of the pleural window.

If the splanchnic nerve is not visible or palpable due to copious subpleural fat, the parietal pleura is opened in the area of the 10th thoracic vertebra with a transverse or ventrodorsal incision starting from the azygos trunk on the right or the descending aorta on the left. The structures coursing in this area are dissected by predominantly blunt technique as far as the dorsal sympathetic trunk until the trunk of the greater splanchnic nerve, several millimeters thick, can be isolated.

T9–11/12 Splanchnicotomy

The caudal splanchnic roots, usually finer than the more cranial roots, converge upon the lesser splanchnic nerve, which supplies the upper abdomen and especially the pancreas. To the extent that they can be demonstrated, they are individually isolated and divided, taking special care to identify the trunk of the lesser splanchnic nerve, which runs just dorsal to the greater splanchnic nerve but cannot always be distinguished from it. In most indications for low denervation, however, it is appropriate to interrupt the greater splanchnic nerve as well.

For deep dissection of the splanchnic trunks, the reflection of the costophrenic recess is incised to gain access to the nerves in the loose connective tissue of the retropleural supraphrenic space on the spinal column.

Right-Left Differences in Dissections of the Sympathetic Nervous System

The sympathetic trunks and their branches are arranged with such extensive lateral symmetry that largely identical conditions prevail for dissections on the right and left sides.

On the right side the operating field is clearly subdivided by the conspicuous trunk of the azygos vein and especially by the azygos arch. The course of the thoracic duct close to the right main splanchnic nerve trunks should be noted in caudal splanchnicotomies.

On the left side, the pulsations of the aorta and aortic arch can transmit motion to the field about the central portion of the sympathetic trunk, which may course near or directly "behind" the descending aorta, especially in obese patients. The apical region, traversed by the subclavian artery, can be more difficult to survey on the left side, the 2nd rib can be more difficult to identify, and the parietal pleura may be thickened near the great arteries.

The thoracic duct courses at the left pleural apex between the sympathetic trunk and subclavian artery before terminating at the junction of the subclavian and jugular veins. Thus, dissection at the 1st and 2nd sympathetic segments must not proceed too far anteriorly (toward the subclavian artery) to avoid thoracic duct injury. Lesions of the main trunk can lead to chylothorax with daily volumes in excess of 1 l, and require aspiration, reinfusion, and clip occlusion.

Vagus Nerve Anatomy

The Right Vagal Trunk

The right vagal trunk passes from the pleural apex to the trachea, which it crosses in its obliquely downward and backward course (Fig. 9.35). The vagal trunk is usually visible or at least palpable in its course between the innominate venous trunk and the trachea (using a cold electrode or probe) along with the cartilaginous tracheal rings.

The vagus nerve then passes beneath the azygos arch toward the esophagus, where the *inferior main group of the right bronchial or pulmonary branches* arises just caudal to or within the concavity of the venous arch and passes over the main bronchus to the lung. The bronchial artery may be closely apposed to the vagal branches, and they may intertwine.

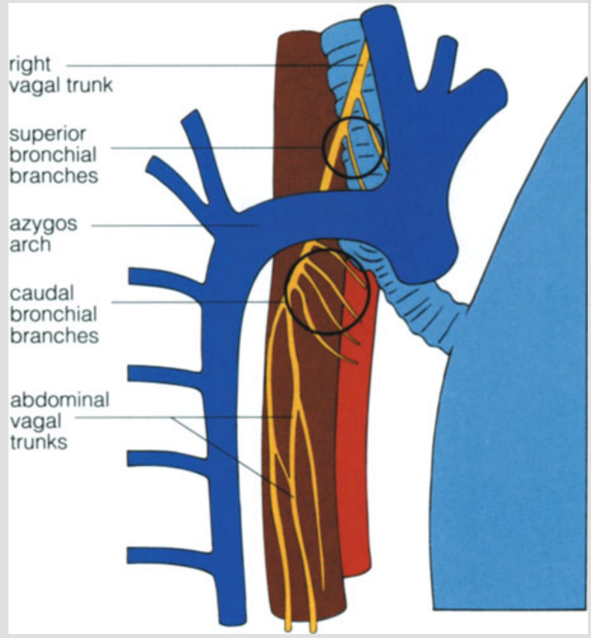


Fig. 9.35. The right main vagal trunk, descending from the apical region, passes obliquely over the trachea, where it gives off superior bronchial branches, and runs beneath the azygos arch, where it gives off the main groups of pulmonary branches to the main bronchus. The abdominal trunks (anterior and posterior) descend on the esophagus

The *superior bronchial branches* originate from the main trunk cranial to the azygos arch (Fig. 9.35).

The *recurrent laryngeal nerve* on the right side arises from the vagal trunk so far cranially, in the apical region, that it is rarely visible.

The *right abdominal trunks* usually divide after the origin of the bronchial branches into one or two large anterior and posterior trunks that descend along the esophagus to the cardia.

The Left Vagal Trunk

The left vagal trunk descends from the pleural apex over the aortic arch, below which it gives off the recurrent laryngeal nerve (Fig. 9.36), which winds back up around the arch.

The inferior main group of the left bronchial branches arises from the main vagal trunk in the hilar region and passes over the main bronchus to the lung.

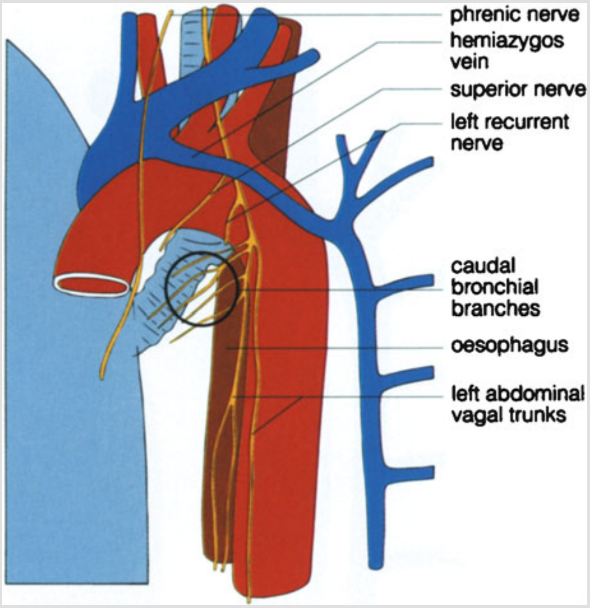


Fig. 9.36. The left main vagal trunk descends to the aortic arch from the apical region, crosses over the aortic arch, and passes beneath the hemiazygos vein, where it gives off fine superior bronchial branches. The large left recurrent laryngeal nerve winds around the aortic arch, in whose concavity the main groups of bronchial branches pass over the main bronchus and can be selectively interrupted. The anterior and posterior abdominal trunks continue their descent on the esophagus; the posterior trunks may partly underlie the aorta, coming between it and the esophagus

Fig. 9.37. The right main vagal trunk descends from the pleural apex (top), runs obliquely over the trachea, where it is visible through the thin pleural layer, and passes beneath the azygos arch. The phrenic nerve apears at upper right on the brachiocephalic trunk. At lower right is the partially collapsed lung

Individual *superior bronchial branches,* usually of smaller caliber, arise from the vagal trunk at the aortic arch level and descend into the hilar region (Fig. 9.36).

Past the origin of the bronchial branches, *the left abdominal trunks* descend on the esophagus to the cardia as anterior and posterior trunks; the latter may continue on to a level below the aorta.

Right Bronchial Vagotomy

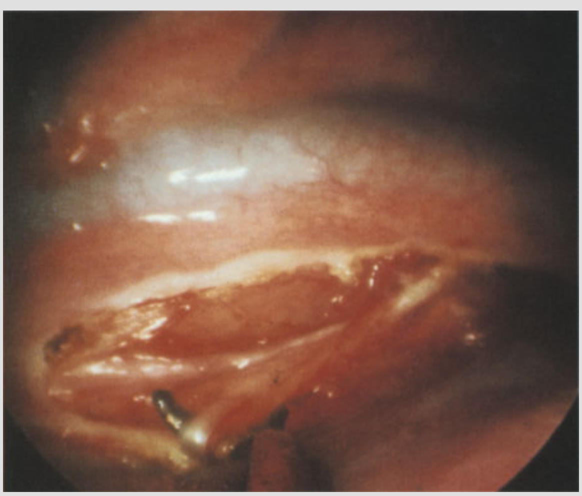
Superior Bronchial Branches

A pleural window is opened over the main vagal trunk, which descends obliquely backward and medially from the pleural apex over the trachea (Fig. 9.37). The large nerve, several millimeters thick, can be isolated by predominantly blunt dissection at the base of the pleural window. Several fine bronchial branches usually arise in this area, passing obliquely to the azygos arch and the root of the lung. Dissecting craniad from the azygos arch, the operator picks up the branches at the border of the main trunk on the curved cautery loop and divides them. If there is copious subpleural fatty tissue, the whole tissue layer can be picked up and divided in stages without individual dissection of the branches until the border of the nerve trunk is free and the nerve can be separated from the mediastinum. The nerve is dissected as far beneath the azygos arch as possible from the cranial side, assisted by undermining of the arch.

Inferior Bronchial Branches

A pleural window is created at the inferior concave border of the azygos arch (Figs. 9.38, 9.39) over the main vagal trunk, which here runs beneath the venous arch, usually passing close to the main bronchus on the medial side. As the pleural window is extended toward the root of the lung, the bronchial or pulmonary

9.38



9.39

Fig. 9.38. Thoracoscopic view of the right mediastinum: The azygos vein (left) receives several large-caliber intercostal veins. At right is the partially collapsed lung, and next to it is the esophagus, on which the vagal branches are faintly visible beneath the thin pleura. The bronchial branches arise at the level of the slightly prominent main bronchus, while the abdominal trunks continue their descent

Fig. 9.39. Origin of the bronchial branches from the main vagal trunk below the azygos arch. The bronchial branches are dissected from the underlying tissue, elevated, and divided with the electrocautery

branches that pass in several large trunks over the main bronchus are isolated, picked up from the bronchus, and divided. Attention is given to the posterior bronchial artery, which may be closely apposed to the nerve bundless or wind around them. Aside from their pulsations, which are not always visible, the arterial branches are more elastic than the nerve branches, so they are distinguishable when optical magnification is used. Bleeding arteries are occluded with clips or bipolar coagulation.

The completeness of the dissection is ensured by visualization of the main trunk, which if possible is traced into the cranial operative field by undertunneling the azygos arch. Fine intermediate bronchial branches that arise in the region of the azygos arch itself are divided. Attention is also given to any fine, lower bronchial branches arising from an anterior abdominal trunk at the caudal border of the hilum.

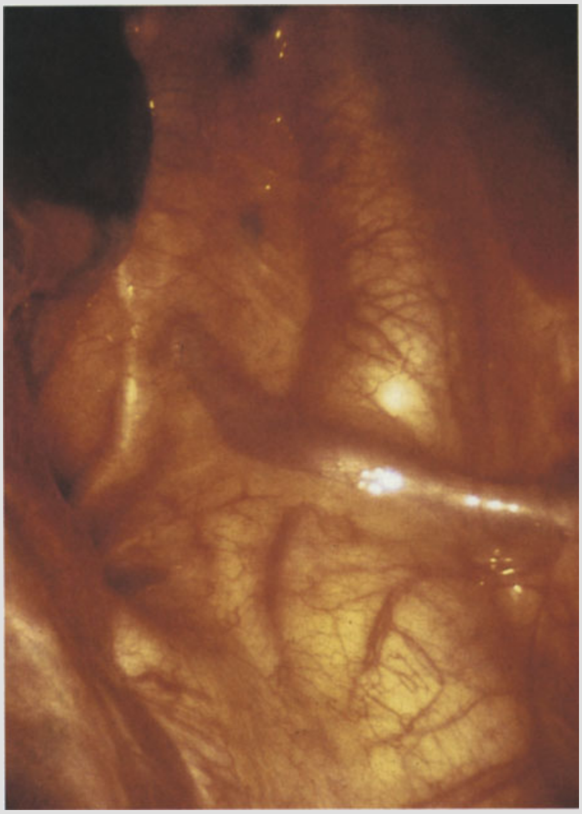
Left Bronchial Vagotomy (Figs. 9.36, 9.40–9.44)

Superior Bronchial Branches

The left superior bronchial branches of the vagus nerve arise from the vagal trunk on the aortic arch and descend obliquely to the pulmonary hilum. During the dissection of these branches, attention is given to the left recurrent laryngeal nerve, a large nerve that runs opposite to the aortic arch, which it winds around before ascending to the trachea.

Inferior Bronchial Branches

The left inferior bronchial branches arise from the vagal trunk in the hilar region (Fig. 9.43, 9.44) and pass in several large bundles over the main bronchus to the lung. Their dissection can be hampered by the strong pulsations of the hilar vessels and aortic arch. After placement of a pleural window over the vagal trunk (Figs. 9.41, 9.42), its course is traced downward from the aortic arch, and the bundles of the bronchial rami, which usually issue from the trunk almost at right angles in this region, are selectively picked up on the curved electrocautery, isolated from the hilar structures, and divided. With a complete bronchial vagotomy, the vagal trunk can be freely mobilized in the direction of the aorta or even displaced beneath the descending aorta. Large lymph node packets, frequently anthracotic, can increase the difficulty of the dissection. Also on the left side, care is taken to protect the posterior bronchial artery.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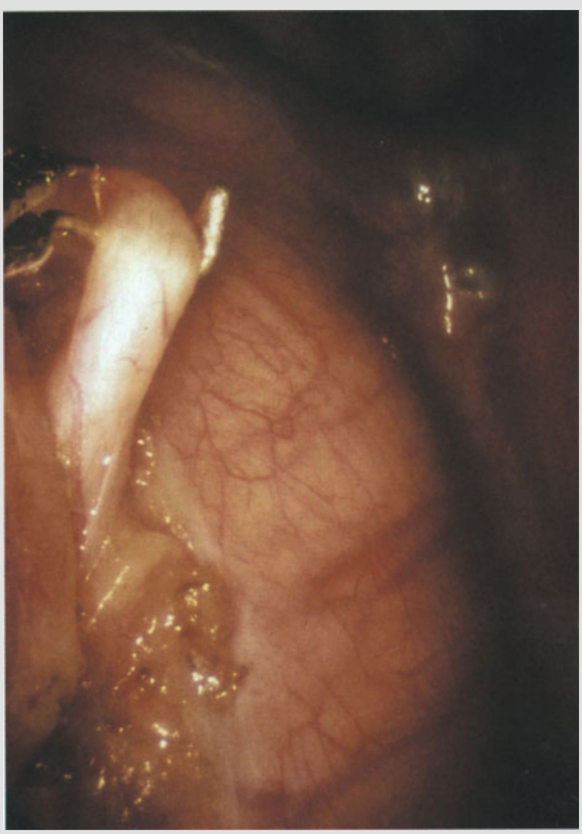
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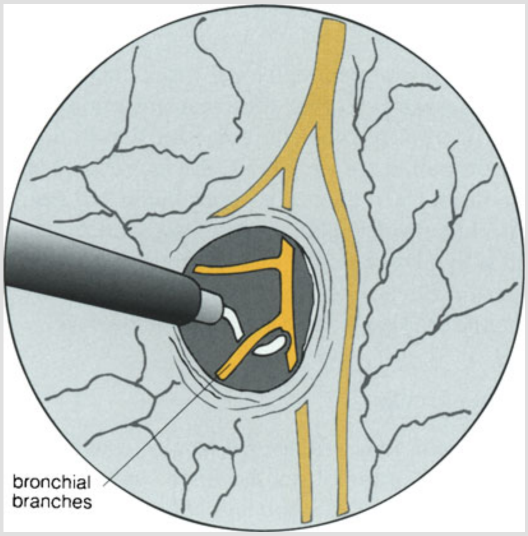

Fig. 9.44. Diagram for Fig. 9.43: the bronchial branches are picked up with the electrocautery and divided past their origin from the main trunk

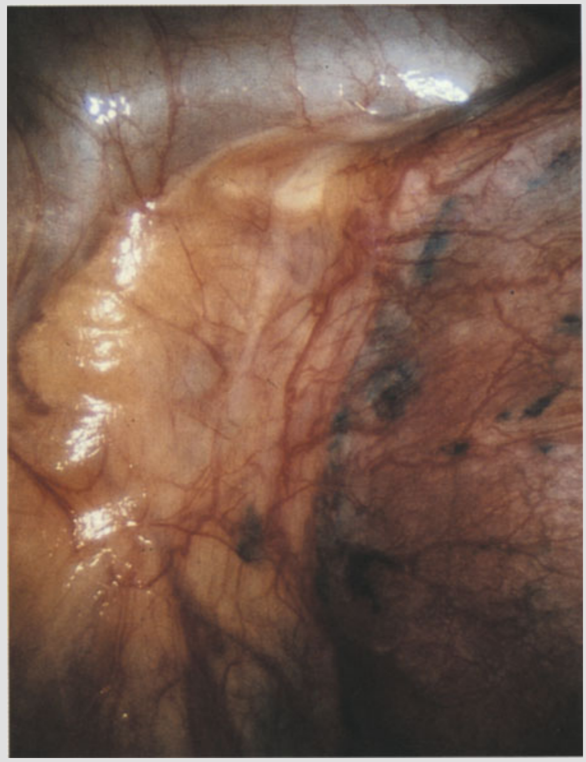

Fig. 9.45. Right thoracic cavity: caudal to the azygos arch are the abdominal trunks, which descend on the esophagus past the origin of the bronchial branches. At right is the partially collapsed lung, at top the azygos arch

Right Abdominal Truncotomy (Figs. 9.7, 9.35, 9.45)

A pleural window is placed on the esophagus caudal to the azygos arch and main bronchus. At this level the vagus nerve has already given off the main group of its bronchial branches and divides into anterior and posterior abdominal trunks, which can be selectively visualized.

Posterior Trunks

The most posterior esophagogastric trunk may pass beneath the ascending azygos vein, in which case it must be lifted out, taking care to protect the nearby thoracic duct, whose injury leads to chylothorax. The safest site for dissection, then, is proximally in the area of the vagus nerve division, where the posterior trunks also tend to be well separated from the azygos vein.

The remaining one or two posterior trunks, usually of larger caliber, are dissected downward from the vagus nerve division (Fig. 9.45) while incising the pleura on the esophagus, picked up from the muscle with the cautery loop, and transected by electrocoagulation. Injury to the esophageal wall is easily avoided during this maneuver unless longitudinal muscle fiber bundles are mistaken for nerve trunks.

Anterior Trunks

The anterior abdominal vagal trunks, usually one or two in number and of relatively small caliber, can likewise be identified caudal to the vagus nerve division on the esophagus and cut with the electrocautery in conditions requiring total truncal vagotomy, such as an anastomotic peptic ulcer or jejunal peptic ulcer. With a primary duodenal ulcer, the procedure can be limited

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Fig. 9.40. Region of the left pleural apex. Below is the aortic arch, and above is the origin of the subclavian artery, which is crossed at its origin by the hemiazygos vein. There the main vagal trunk passes beneath the vein and over the aortic arch and is distributed within its concavity. At left is the hilar region of the lung

Fig. 9.41. A pleural window is established in the concavity of the aortic arch over the main vagal trunk

Fig. 9.42. Here the vagal trunk is dissected free and can be mobilized for identification. The recurrent laryngeal nerve also arises at this level, winding below the aortic arch before ascending

Fig. 9.43. Vagal trunk exposed at a slightly more caudal level, where the main group of bronchial branches pass to the main bronchus in the hilar region

to the more selective posterior truncotomy since the anterior abdominal trunks mainly supply the antral region.

Left Abdominal Truncotomy (Figs. 9.8, 9.36, 9.46)

On the left side as well, the vagus nerve division on the esophagus can be exposed through a pleural window placed caudal to the main bronchus and the origin of the main group of bronchial vagus branches. The dissection is more difficult on the left side, because the nerve usually begins to divide while still on the pulmonary hilum within the aortic arch; the pulsations of the aorta, pulmonary vessels, and pericardium transmit motion to the operative field; the mediastinal pleura is often thickened and fatty; and nodal clusters are commonly encountered in the hilar region.

Fig. 9.46. Left pleural cavity: after placement of a pleural window, a large posterior abdominal vagal trunk has been pulled forward from below the descending aorta (at right) and elevated from the underlying esophagus, where it can be safely divided just caudal to the hilar region

Posterior Trunks

The posterior abdominal vagal trunks may pass beneath the aorta, so that the most posterior esophagogastric trunk between the esophageal wall and aorta must be pulled forward for safe electrocoagulation. Unipolar high frequency is contrainidicated near the aorta, but the LF platinum-iridium cautery can be used with relative safety. The remaining larger-caliber posterior trunks, one or two in number, can be dissected on the esophagus even at a more caudal level.

Anterior Trunks

The anterior abdominal vagal trunks, usually one or two in number and of small caliber, can be identified and sectioned on the esophagus below the level of the pulmonary hilum in cases requiring total truncal vagotomy (e.g., jejunal peptic ulcer; see above, Right abdominal Truncotomy, Anterior Trunks). There is no danger of esophageal wall injury if the nerve trunks are bluntly dissected with the cautery loop, picked up from the muscular coat, and divided with the LF cautery.

Cardiac Nerve Ramisection

The sympathetic cardiac nerves originate from the sympathetic trunk between T1 and T4–5. On endoscopic microsurgery they can be identified as fine branches at the ventral ganglionic margin and severed (Fig. 9.47). To ensure that the desired effect is achieved it is advisable also to inactivate the neural anastomoses on the subclavian and mammary arteries by dividing the parietal pleura except for the adventitia. Since the cardiac sympathetic fibers in the sympathetic trunk are long fibers and run through the cervical ganglia, additional interganglionic divisions may be performed at T1–2, T2–3, and T3–4 (see "T3 Interganglionic Sympathectomy" and "T2 Interganglionic Sympathectomy", p. 123), if it seems the selective cardiac nerve ramisection might not be sufficient (fibers ascending directly to the cervical ganglia!), and provided there is no contraindication to the cutting of the sudomotor and vasomotor fibers supplying the cranial quadrant (face, arm, and upper thorax).

Interruption of the sympathetic cardiac fibers not only symptomatically eliminates pain in angina pectoris but also lower the oxygen consumption of the heart muscle at a given level of cardiac work (Eckstein et al.).

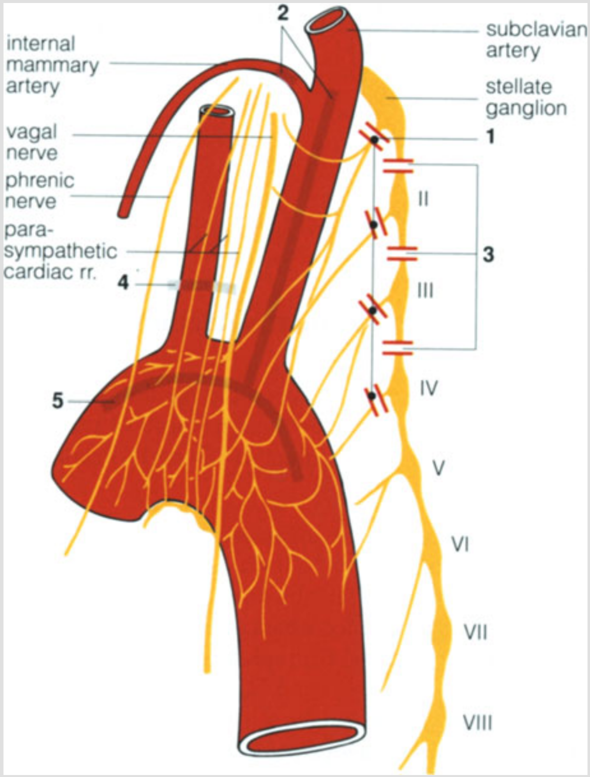

Fig. 9.47. Autonomic denervation for angina pectoris. *1* Division of sympathetic cardiac nerves at ventral margin of sympathetic trunk ganglions T1 to T4–5. *2* Ramisection of anastomoses on subclavian and mammary arteries. *3* Interganglionic sympathectomy at T1–2, T2–3, and T3–4. *4* Division of parasympathetic cardiac rami between vagal trunk and phrenic nerve. *5* Resection of superficial cardiac plexus on aortic arch

The parasympathetic cardiac rami descend from the capula of the pleura between the vagus nerve and the phrenic nerve to the aortic arch, where they form the superficial cardiac plexus. They are most reliably severed by dividing the pleura at the aortic arch and resecting the cardiac plexus except for the adventitia; at the latter site some sympathetic cardiac fibers are also cut.

Interruption of the parasympathetic cardiac fibers should eliminate the vasoconstrictor effect of the parasympathetic nervous system on the heart. Combined division of the sympathetic and parasympathetic fibers therefore appears the physiologically most promising method of dealing with angina pectoris.

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10 Thoracoscopic Ligation of Pleural Bullae and Parietal Pleurectomy for Recurrent Spontaneous Pneumothorax. Treatment of Empyema and Pericardiectomy

A. Cuschieri and L. K. Nathanson

Introduction

Recurrent spontaneous pneumothorax occurs in 4.3 per 100000 patients per year with a male:female ratio of 5:1. Spontaneous pneumothorax of less than 20% hemithoracic volume in an otherwise healthy adult who is not breathless is best managed by observation and selective use of oxygen therapy. However, over 70% of patients present with lung collapse greater than 25%. Therefore, the majority of patients require active management with intercostal tube drainage.

Surgical treatment is needed in certain specific patient groups. It entails the identification of the cause of the air leak and its closure with maximal preservation of lung substance, followed by measures directed at promoting permanent adhesion of the visceral pleura of the expanded lung to the chest cavity. Thoracotomy with parietal pleurectomy (or pleural abrasion), with excision, oversewing or stapling of any visible pleural blebs and postoperative tube drainage is an effective and well-validated procedure. A long-term study with 2–8-year follow-up showed no recurrence and no significant impairment of the mechanical efficiency of respiration. However, in this report 7.7%–16.6% reduction in vital capacity persisted for 2 months and returned to preoperative values only at 5 months. This was attributed by the author to the trauma of the healing wound impairing ventilatory function. The smaller axillary thoracotomy incisions have partially addressed this problem, but the trade-off is cramped exposure during excision of the pleural bullae and pleurectomy. Exposure of the pleural cavity with the thoracoscope linked to the charge-coupled device (CCD) camera and external video monitor is superb and is combined with three accessory cannulae for introduction of instruments. The pleural bulla is ligated in situ, and a pleurectomy is performed by stripping away the upper two-thirds of the parietal pleural by sharp and blunt dissection.

Indications and Patient Selection

The indications for thoracoscopic ligation of bullae and pleurectomy are indentical to those of the standard open surgical treatment involving thoracotomy. They are:

1. Failure of the lung to re-expand due to persisting air leak. This occurs in 4%–14% of patients; management is by intercostal tube drainage.
2. Ipsilateral recurrence which increases in likelihood from 16% after the first episode to 80% following the third.
3. Contralateral occurrence.
4. Bilateral simultaneous pneumothorax which is life threatening.
5. Special-risk groups such as aircrew and divers.

Anaesthesia

General anaesthesia can be performed with standard endotracheal single lumen tube intubation. Where it is felt advantageous to use a double lumen tube to aid collapsing the lung, this can be considered. However, a portal of entry for gas into the pleural space is still required. In addition, pleural bullae are best visualised with only a partially collapsed lung. Furthermore, the risk of postoperative atelectasis is increased by complete intraoperative collapse of the lung, especially in patients who have had partial collapse of the lung for some time preoperatively and in patients with chronic obstructive airways disease.

Patient Positioning, Skin Preparation and Draping

The patient is placed on the operating table in the posterolateral thoracotomy position with the arm held abducted to ensure maximal superior displacement of the scapula. The table is split to maximise the spread of the intercostal spaces.

The skin of the entire chest wall is prepared for surgery by cleaning with disinfectant soap, followed by the application of an alcohol-based antiseptic lotion. Drapes are applied to isolate the operative field which must extend from the midscapular level superiorly to the 12th rib inferiorly, and from the sternal margin anteriorly to the vertebral column posteriorly.

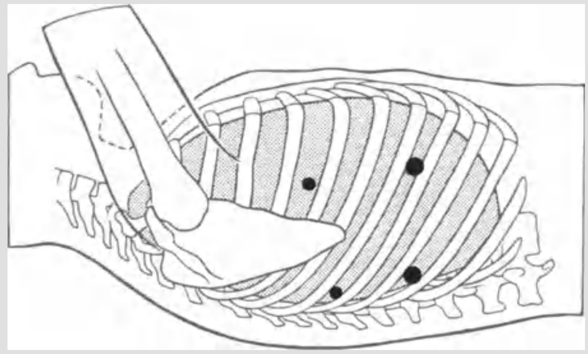


Fig. 10.1. Sites for the placement of the cannulae for thoracoscopic ligation of bullae and pleurectomy. The posterior cannulae must be placed anterior to the angle of the ribs to avoid injury to the intercostal nerves

Layout of Ancillary Instruments and Positioning of Staff

The surgeon operates facing the back of the patient with the scrub nurse on the same side but further down. The assistant stands on the opposite side of the operating table. The disposition of the associated instrumentation is to some extent dependent on the layout of the operating theatre, but, if possible, the electronic insufflator, light source, telescope warming system, irrigation system and electrosurgical unit should be stacked behind the surgeon. Ideally two television monitors should be used, one opposite the surgeon and scrub nurse, and the other facing the assistant, both being sited close to the head end of the operating table.

Specific Instrumentation and Consumables

In addition to the standard laparoscopic equipment, the following instruments should be available: 5.0 mm forward-viewing telescope, pledget swab holder and two needle holders (3.0 and 5.0 mm). The important consumables are preformed chromic catgut endoloops (Ethibinder, Surgitic), intercostal drain and 3/0 polydioxanone sutures or polysorb sutures mounted on endoski needles.

Operative Steps

Cannulae Placement

A two-handed dissection technique is essential. For this reason, four cannulae are needed. The ideal position of these is shown in Fig. 10.1. The inferior two are 11.0 mm in diameter for use of the 10.0 mm 30° forward-oblique telescope and insertion of a gauze pledget to aid blunt dissection. The upper two cannulae, both 5.5 mm, are used for the insertion of grasping forceps, scissors and the sutures/ligatures. Correct positioning of these cannulae is very important. Placement must be such that, by moving the viewing thoracoscope from the anterior to posterior position and by using unoccupied cannulae for instruments, exposure as well as instrumental access is available to the entire upper pleura and lung surface. The use of the 0° forward-viewing optic is not advised because of the rigidity of the thoracic cage. The oblique view allows one to look around the curvature of the lung and minimise the amount of instrumental lung retraction required. In fact, an optic with more oblique forward viewing, e. g. 45°, may on occasions enhance the exposure.

Initial Insufflation

Usually, the patient has a pneumothorax present at the time of surgery or has an intercostal tube drain (ITD) in place. In the case of a pneumothorax already being present, the initial (5.5 mm) cannula is introduced blindly into the pleural space with care. The lung can then be collapsed further to improve exposure by connection of the CO_2 insufflator to this cannula with the automatic cut-off pressure set at 6 mmHg. If the lung is fully expanded with an ITD, then initial collapse of the lung is obtained by connection of this to the insufflator and allowing 500 ml CO_2 gas into the pleural space. The patient is carefully monitored during this phase to detect any adverse haemodynamic effects consequent on mediastinal shift due to the raised intrathoracic pressure. The initial cannula can then be introduced in the same fashion. If, however, the lung is expanded without an ITD, then the initial cannula must be inserted under direct vision (see Chap. 8) with the insufflator connected to the trocar. When the oblique tip of the cannula, as it is rotated, breaches the parietal pleura, the combined effect of the insufflating gas pressure and lung compliance results in rapid separation of underlying lung from the cannula tip obviating injury to the visceral pleura. This process is carefully monitored visually with the forward-viewing 5 mm thoracoscope. Once the first cannula is positioned, the accessory ones are inserted under direct vision, with the position from within being apparent by fingertip indentation of the intercostal space. Penetration is easily controlled by this technique, and the risk of damage to lung parenchyma or mediastinal structures is avoided.

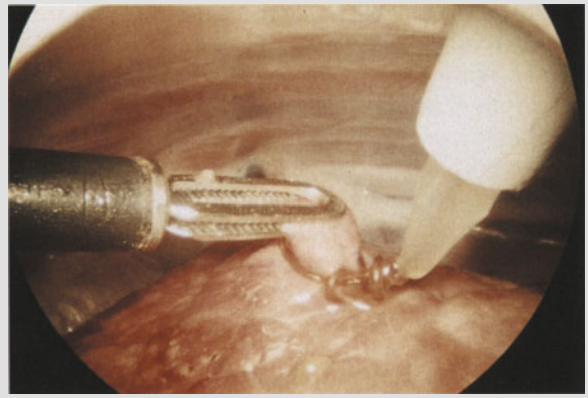


Fig. 10.2. The preformed endoloop is placed around the base of the bulla whilst this is help up by the grasping forceps. The Roeder slip knot is then tightened and locked in place securing the base of the bullae. The excess ligature is cut about 1.0 cm from the knot

Initial Inspection of the Lung

The lung surface is inspected with the 30° forward-oblique telescope from its apex downwards, looking for bullae which constitute the most common source of recurrent air leaks into the pleural cavity. The lung can be gently displaced with round-tipped instruments to reveal all its surface. It is important that this inspection is thorough. In otherwise fit patients with recurrent pneumothorax, the bullae are predominantly sited in or around the apical segment of the upper lobe and, although usually multiple, are located close to each other. In patients with obstructive airways disease, the position of the bullae and cysts tends to be more widespread and often involves the lower lobe. There is a small group of these patients in whom, despite the presence of a refractory pneumothorax, surface bullae cannot be identified at thoracoscopy despite a careful and thorough search (see below). If the leak cannot be identified, the chest cavity, should be filled with *warm* (38° C) Ringer's lactate solution to identify the site by the bubbling. It is very important that the solution infused is warmed to the night temperature as otherwise some bradycardia may be induced.

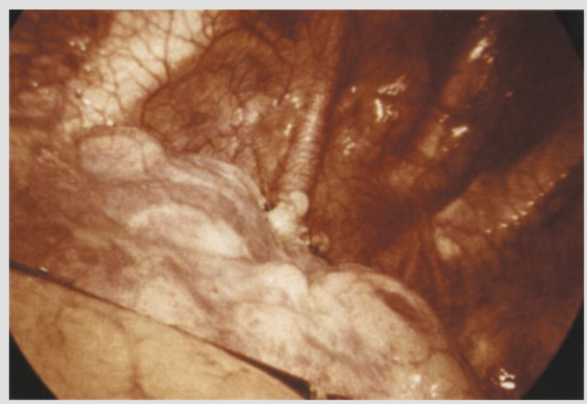


Fig. 10.3. Completed ligation of the apical bullae

Ligature/Oversewing of Bullae

Ligation of Apical Bullae

Rapid control of the bullae by ligation is made possible with the endoloop using chromic catgut and a pretied Roeder knot (Fig. 10.2). The loops with their push-rod are loaded into the suture applicator and then into the cannula. Once the loop is in the pleural cavity, the bulla is grasped within the loop and held steady while the one-way slip knot is tightened against the push-rod (Fig. 10.3). This knot swells as it hydrates so increasing its ability to resist slipping in the reverse direction. We have previously demonstrated that chromic catgut tied with the Roeder slip knot can withstand a tension of approximately 1000 g before reverse slipping occurs. This is likely to be far in excess of the force exerted by the pleural bleb, and if any reservation is held, a second ligature can be easily applied. We emphasise that synthetic ligatures used with this knot only sustain half this tension.

Oversewing of Large Bullae or Cysts

Large bullae or cysts encountered in patients with obstructive airways disease cannot be ligated with the endoloop technique. These are closed by the inversion-oversewing technique using continuous suturing with 3/0 polydioxanone. Although some surgeons practise excision prior to suturing, this is less satisfactory than the above. The technique of inversion oversewing is shown in Fig. 10.4. The techniques for continuous suturing are described in Chap. 7.

The endo GIA stapler (AutoSuture) is a useful instrument. When activated, this stapling device, which is introduced down the 12 mm cannula, fires two rows of six staples and has an integral blade which is slid to divide between the two stapled lines. It is possible to seal large bullae and cysts with this stapler although the technique of precise inversion of the cyst wall is not possible with this device. At this stage one cannot envisage any material advantage to the use of the Endo GIA stapler over the suturing technique described above in the treatment of large cysts or bullae except for ease of use.

Fig. 10.4 a–c. Technique of inversion oversewing for large bullae/lung cysts. **a** The apex of the bulla or cyst is incised over a distance of 1.0 cm. This results in immediate deflation. The interior of the bullae is inspected for identifiable bronchiolar leaks which require individual suture ligation. **b** A continuous suture grasping 1.0 cm superficial bites of adjacent lung parenchyma and perimeter of the cyst wall is used to approximate the edges of the lung substance together over the inverted wall of the deflated bullae or cyst. This forms an internal packing filling the internalised defect and sealing the suture line from the inside. **c** Alternatively the base of large bullae together with the adjacent lung tissue is stapled using the endo GIA

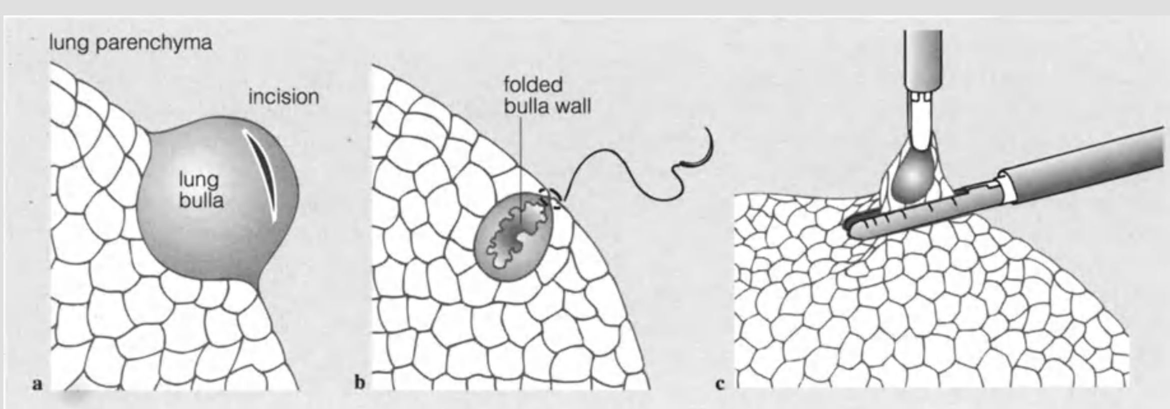
Stapling of Bullae and Wedge Pulmonary Resections

There is no doubt that the endo GIA stapler facilitates closure/resection of large or multiple bullae. Our clinical and experimental studies have shown that better results are obtained by using the smaller stapler head (white). The optimal technique for stapler closure/resection entails the preliminary apical puncture of the bulla. With the bulla tented upwards, the stapler is then placed just below the junction between the walls of the bulla and the lung parenchyma. The stapler head is closed and fired in this position. The bulla is then extracted. Basically the same technique is used for pulmonary wedge resections. These may require multiple firing of three or four stapler heads. Often a combined technique of endo GIA stapling and endoloop knotting is required.

Parietal Pleurectomy

The pleural strip begins by marking the posterior, anterior and inferior limits of the dissection with scissors division of the parietal pleura. Anteriorly, the limit is the internal thoracic artery, readily traced down from the subclavian artery as it arches over the apex of the thoracic cavity. The posterior limit on the left side is the lateral border of the thoracic aorta, while on the right the limit is the azygos vein. The inferior limit is taken as the level of the inferior two cannulae, which results in an upper two-thirds pleurectomy.

Grasping forceps lift and steady the pleura whilst it is initially incised with scissors. Once the avascular plane is entered, blunt pleural stripping of the chest wall may be expedited with a pledget introduced through a reducing tube and 11.0 mm cannula. An important aspect of this technique is for the surgeon to use instruments in each hand while viewing the opera-



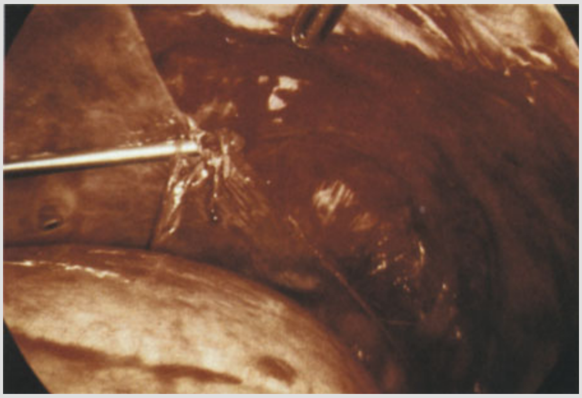


Fig. 10.5. Partially completed pleurectomy

tion on the video screen. This gives important tactile feedback of the force exerted on tissue. As the procedure progresses, the position of the telescope and dissecting instruments requires to be changed to allow efficient dissection. As the pleura is lifted, it is excised in segments and extracted via the cannula to clear the operative field. Care should be taken at the apex of the thoracic cage. The sympathetic trunk lying over the neck of the ribs must be preserved. Injury is possible by traction on the pleura tenting the chain up, easily resulting in scissors, diathermy or traction injury. The upper two-thirds of the pleura can be rapidly dissected in this way (Fig. 10.5). If desired, the lower pleura can be destroyed by contact with a monopolar diathermy probe. Any bleeding that occurs can easily be controlled by coagulation or ligature. Blood clots are washed with warm saline irrigation and the pleural space aspirated dry prior to completion of the operation. An ITD is inserted via the anterior 11 mm cannula site. The cannulae are withdrawn, and the skin is approximated with interrupted sutures.

In some patients no pleural bullae can be detected. In this situation, the edges of the lung near the fissures should be systematically viewed to avoid missing a small bulla. Once the surgeon is satisfied that no bullae are present, an extensive pleural strip with endocoagulation of any residual parietal pleura is performed. Alternatives to pleurectomy include abrasion with polyethylene pledget, electrocoagulation and photocoagulation (laser). Argon beam spray coagulation is the must efficient and quick method. When used it is important that one of the thoracic access ports is kept completely open as otherwise a dangerous rise in intrathoracic pressure will ensue.

Intraoperative Complications

The lung may be damaged by rough instrumental retraction. Unless extensive, this will usually seal postoperatively without resort to ligature or direct suture. It is worth emphasising again the importance of avoiding injury to the lung parenchyma or mediastinal structures during instrument insertion into the pleural cavity while this is out of the operator's field of view on the video screen. This is especially likely to occur when the optics are close up to the structure during pleural dissection.

During blunt dissection, the pledget may become dislodged from its grasping forceps and fall out of view. This is best prevented by carefully securing the locking mechanism of the grasping forceps. It is our practice to augment the locking mechanism (since this often fails) by a sterile (autoclaved) rubber band wound round the handles of the instrument. If dislodgement does occur and the pledget cannot be immediately found, the grasping forceps is exchanged for the suction/aspiration cannula. After 30° head-up tilt of the patient, pressurised warm saline is copiously irrigated over the lung to wash all blood and clots vigorously. The view is then directed down to the costophrenic angle, and, after aspiration of the fluid by the suction cannula, the pledget will be found. Damage to the intercostal nerves caused by the trocars inserted through the intercostal space can cause morbidity due to neuralgia. For this reason, the posterior cannulae should be inserted anterior to the angle of the ribs where the nerves are protected in the intercostal groove. The conically shaped trocars may also have some benefit here as they have more of a muscle-splitting effect during entry and are potentially less likely to damage muscles, vessels and nerves than sharp pyramidal trocars.

Postoperative Care

Postoperative lung re-inflation is usually rapid without the patchy collapse/consolidation frequently encountered after open surgery. We attribute this beneficial effect to the avoidance of handling and retraction of the lung during endoscopic surgery since the pulmonary parenchyma can be kept collapsed to the desired level with intermittent CO_2 insufflation. This, combined with the free chest wall movement and improved ability to cough, due to avoidance of a thoracotomy wound, often results in full lung expansion and removal of the ITD by the 2nd postoperative day.

Pain is minimal and consists of posterior chest wall and shoulder soreness usually during the first 12 h after the procedure. It is treated with standard analgesic medication using intramuscular opiates. Antibiotic therapy is not administered unless a chest infection develops postoperatively.

In patients with recurrent pneumothorax but otherwise normal lung parenchyma, postoperative recovery is rapid, and discharge from hospital is usually on the 3rd or 4th postoperative day. Patients with obstructive airways disease require a significantly longer period of recovery because full lung expansion is slower and may take several days to weeks. Often these patients require positive pressure ventilation for the first 24 h after surgery. The main reason for the delay in achieving full lung expansion in these patients is due to the loss of lung compliance in this disorder.

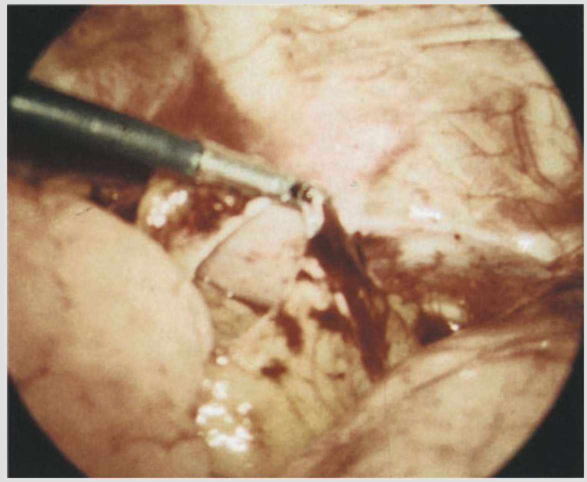


Fig. 10.6. Endophoto of pericardial window for pericardial effusion

Clinical Results and Discussion

To date, our experience with thoracoscopic ligation and pleurectomy has been entirely favourable. The procedure achieves the same early results as those obtained by thoracotomy, and there is no reason to expect a lower cure rate than that obtained by open surgery since the same procedure is performed. Our longest follow-up now extends to 36 months, and there has been no instance of recurrence of the pneumothorax subsequent to discharge from hospital. The significant complications encountered in the first twenty five patients were two: rupture of bulla in the contralateral lung during the postoperative period in one patient and intercostal neuralgia in another. In the latter patient, one of the 5.5 mm posterior cannulae was inserted behind the angle of the rib and resulted in damage to the intercostal nerve. Since that time, we have ensured that no cannula is inserted posterior to the angle of the rib and have not encountered a repetition of this complication. We were particularly impressed with the outcome of a patient with chronic respiratory failure due to severe obstructive airways disease who developed a pneumothorax with complete lung collapse unresponsive to conservative measures. This patient was considered to be unfit for thoracotomy. Although it took 2 weeks to achieve full lung expansion after her thoracoscopic procedure, she made a full recovery and was discharged from hospital 3 weeks after her operation. We have since encountered one major complication in a patient who developed staphylococcal empyema after ligation of multiple bullae.

Treatment of Empyema

Currently, using a similar technique, we are evaluating the thoracoscopic approach to the treatment of thoracic empyema. Provided the disease has not reached a chronic stage, evacuation of pus and debris and decortication with adequate lung expansion can be achieved in 70%–80% of patients.

Pericardiectomy

The thoracoscopic approach is ideally suited to the management of patients with pericardial disorders and effusions. The pericardium can be approached though the right or left approach although we favour the latter. The technique involves grasping the pericardium anterior or posterior in the phrenic nerve and pericardiophrenic vessels using a pericardial hook and opening it with twin active scissors. A sufficient window is then cut for biopsy and to decompress the pericardial cavity (Fig. 10.6). A sample of the pericardial fluid (blood-stained, purulent or clear) is taken for culture. Following decompression a flexible endoscope can be introduced for inspection of the myocardium and inner aspects of the residual pericardial sac.

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11 Thoracoscopic Oesophageal Myotomy for Motility Disorders

A. Cuschieri, L. K. Nathanson, and S. M. Shimi

Introduction

Oesophageal motility disorders fall into two major categories: disorders of oropharyngeal transfer and those which affect the body of the oesophagus and the lower oesophageal sphincter. They cause a considerable amount of symptomatic disability such as dysphagia, odynophagia, regurgitation and non-cardiac chest pain. In addition, they predispose to the development of aspiration pneumonitis, especially in patients with intractable symptoms. This chapter deals with the thoracoscopic surgical treatment of motility disorders affecting the body and lower sphincter of the oesophagus.

Motility Disorders of the Oesophageal Body

Motility disorders are further subdivided into specific and non-specific. The important specific motility disorders are: diffuse oesophageal spasm, symptomatic oesophageal peristalsis (nutcracker oesophagus) and achalasia. They have a distinctive manometric pattern and require specialized oesophageal function tests for accurate characterization. These investigations include detailed oesophageal manometry to obtain the pressure profile within the oesophagus and the response to wet and dry swallows, oesophageal transit studies using a radiolabelled liquid or solid bolus and 24-h ambulatory pH monitoring to establish the presence or absence of associated acid reflux and defects in the oesophageal acid clearance mechanism.

Achalasia

The diagnosis of achalasia is usually made by clinical history, barium swallow, upper gastrointestinal endoscopy, manometry and scintigraphic transit studies. The distinctive manometric features of achalasia are: elevation of the resting pressure of the oesophagus, absence of peristaltic contractions in the body of the oesophagus in response to swallowing, failure of a normotensive or hypertensive lower oesophageal sphincter to relax on deglutition and increased sensitivity of the oesophageal smooth muscle to cholinergic agonists.

Diffuse Oesophageal Spasm

This disorder is characterized by substernal chest pain simulating angina-like attacks or dysphagia or both. The radiological appearances on the barium swallow demonstrate localized non-progressive spastic contractions in the body of the oesophagus (rosary bead or corkscrew oesophagus). Manometry identifies an increased incidence of non-peristaltic high-amplitude contractions.

Nutcracker Oesophagus

Nutcracker oesophagus is the second most common cause of non-cardiac chest pain (normal coronary angiograms). It is characterized by peristaltic contractions of increased amplitude and duration. Oesophageal manometry is essential for its diagnosis using accepted criteria of mean amplitude of contractions (>180 mm Hg) and duration of contractions (>7.5 s).

The non-specific disorders do not conform to any specific manometric profile and are often secondary to oesophageal reflux disease. This is the most common cause of non-cardiac chest pain.

Management and Indications for Surgical Treatment

Achalasia

The medical management of patients with achalasia is unsatisfactory, and relief of dysphagia is obtained either from balloon dilation or cardiomyotomy. There is

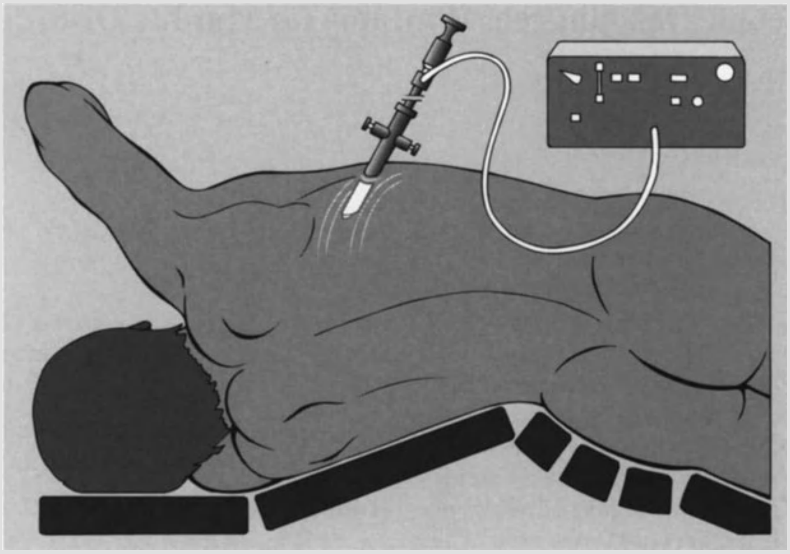


Fig. 11.1. Position of the patient for thoracoscopic myotomy: left posterolateral approach. The left chest wall is arched upwards by splitting the table to ensure maximal width of the intercostal spaces, and the left arm is held well abducted

considerable controversy regarding the operative or endoscopic management of the condition. The proponents of balloon dilation resort to surgical treatment only for failures or recurrence after this procedure. Others advocate cardiomyotomy in all the patients. Even amongst surgeons, opinion is divided as to whether the operation is best performed through the thorax or the abdominal route and whether an additional antireflux procedure is needed. Careful review of the reported literature on the subject indicates the following:

1. Although the results of balloon dilation are equivalent to those of cardiomyotomy in the short term, the long-term results are better following surgical treatment.
2. The incidence of gastro-oesophageal reflux is much lower after a thoracic cardiomyotomy than after the abdominal procedure. The low incidence of reflux after thoracic cardiomyotomy does not justify the routine addition of an antireflux procedure. This is an undoubted advantage as any form of fundoplication is undesirable in patients with defective or absent effective peristalsis in the oesophageal body.

Nutcracker Oesophagus and Diffuse Oesophageal Spasm

The current management of patients with non-cardiac chest pain is unsatisfactory. Most are associated with nutcracker oesophagus and, less commonly, diffuse oesophageal spasm. Medical management includes antireflux medication and the use of nitrates, calcium antagonists and cimetropium bromide. The relief with these agents is uncertain, and controlled studies have found these drugs to be no better than placebo in relieving chest pain associated with diffuse oesophageal spasm and nutcracker oesophagus. Therapy with calcium channel blockers often precipitates or exacerbates existing gastro-oesophageal reflux. Only 5% of patients with intractable symptoms unresponsive to medical treatment or who require doses of these agents producing substantial side effects are referred for surgical management. This involves long oesophageal myotomy tailored to the extent of the manometric abnormality with or without an antireflux procedure.

Anaesthesia, Patient Positioning and Preparation

General anaesthesia is carried out with standard endotracheal double lumen tube intubation. The patient is placed on the operating table in the left prone posterolateral thoracotomy position with the arm held well abducted to ensure maximal superior displacement of the scapula. In addition, the operating table is split to arch the left hemithorax and obtain maximal spread of the intercostal spaces (Fig. 11.1).

Skin Preparation and Draping

The skin in prepared with medicated soap (Hibiscrub) followed by the application of skin antiseptic of the surgeon's choice. The operative field is draped such that the entire rib cage is exposed from mid-scapular level above to the 12th rib below, and the sternal border anteriorly to the vertebral column posteriorly.

Position of Instrumentation and Staff

The position of the staff and instrumentation in relation to the patient placed in the prone posterolateral left thoracotomy position is shown in Fig. 8.2. For most of the procedure the surgeon operates from the right side of the operating table.

Details of Specific Instrumentation and Consumables

In addition to the standard laparoscopy set, the following are needed:

1. 5.0-mm optic
2. Telescope holder
3. Corrected beam splitter
4. L-shaped electrosurgical hook knife
5. Twin-action dissecting scissors
6. Flexible fibre-optic endoscope

Insertion of Flexible Endoscope

Following induction of anaesthesia, a standard forward or oblique-viewing flexible endoscope is introduced and the tip placed just below the oesophagogastric junction. Once in position, the light is switched off. This endoscope is subsequently used for two purposes: identification of the oesophagus in the aortovertebral gutter by transillumination and endoscopic lifting of the organ to facilitate exposure and dissection. This helpful adjunct is advisable for both cardiomyotomy and long oesophageal myotomy.

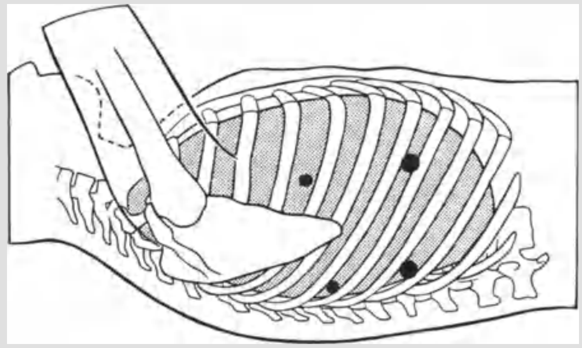


Fig. 11.2. Position of cannulae

Cannulae Placement

As shown in Fig. 11.2, four to five cannulae are used. The inferior two are 11.5 mm in diameter for use of the 10.0-mm 30° forward-oblique telescope and insertion of clip applicator and pledget swab for blunt dissection. The upper two to three cannulae, all 5.5 mm, are used for the insertion of grasping forceps, scissors and electrosurgical hook knife. Accurate placement of these access cannulae is critical for adequate exposure and ease of dissection. It is important that the posterior cannulae are placed anterior to the angle of the rib to avoid damage to the intercostal nerve which can produce distressing neuralgia postoperatively.

The first cannula to be inserted is the anterior upper 5.5-mm one (fourth interspace). This is carried out under direct vision using a special technique which obviates the risk of damage to the lung parenchyma (see Chap. 8). The trocar and cannula assembly is introduced through a small stab incision in the intercostal muscle space. After removal of the trocar, the cannula is connected to the electronic insufflator set at minimal flow and a pressure of 6.0 mm Hg. A 5.0-mm telescope attached to the endocamera is then introduced inside the cannula such that the tip of the optic lies just proximal to the oblique tip of the cannula, thereby visualizing the stretched tissues ahead of the latter device. The cannula is then carefully "reamed" through the tissues by rotation with gentle force exerted from the wrist until the parietal pleura is breached, when the combined effect of the insufflating CO_2 flow pressure and lung compliance results in collapse of the underlying lung away from the cannula tip. The remaining cannulae are then inserted under direct vision after their optimal position is ascertained from within by the indentation of the relevant intercostal space.

Intrathoracic Pressure and Cardiac Monitoring

The safety of the procedure is dependent on the avoidance of mediastinal shift which will occur rapidly and lead to hypotension and cardiac arrythmias if the pressure within the hemithorax exceeds 8.0 mm Hg. In our experience, a working pressure of 6.0 mm Hg (preselected on the electronic insufflator) provides this safety margin and ensures satisfactory lung collapse.

The essential monitoring includes: ECG, central venous pressure, arterial pressure and urine output. A Swan-Ganz catheter for monitoring of the pulmonary wedge pressures and cardiac output is only used in patients with established heart disease.

Operative Steps

Exposure of the Lower Oesophagus

This step is common to both cardiomyotomy and long oesophageal myotomy with minor differences which are outlined below.

The first landmark to be identified is the inferior pulmonary ligament. This is divided with scissors using electrocautery to small vessels crossing this membrane (Fig. 11.3). The identification of the lower oesophagus is then readily achieved by switching the light source of the flexible endoscope and dimming the light to the thoracoscope endocamera assembly.

The mediastinal pleura over the hiatal margin is divided. Several small vessels require control by electrocoagulation during this step. It is important that a dry field is kept as even minor oozing results in pooling of blood in the aortovertebral gutter with impairment of vision. The dissection of the upper surface of the lower oesophagus is considerably facilitated by flexing the tip of the endoscope forwards, thereby lifting the organ from its gutter. Complete mobilization of the entire circumference is unnecessary, the dissection being limited to exposure of the upper half of the circumference of the oesophagus.

Long Myotomy for Nutcracker and Diffuse Oesophageal Spasm. The mobilization of the lower oesophagus is completed when the phreno-oesophageal membrane and its attachment to the oesophago-gastric (OG) junction have been exposed. At this stage the vagal trunks are identified and preserved.

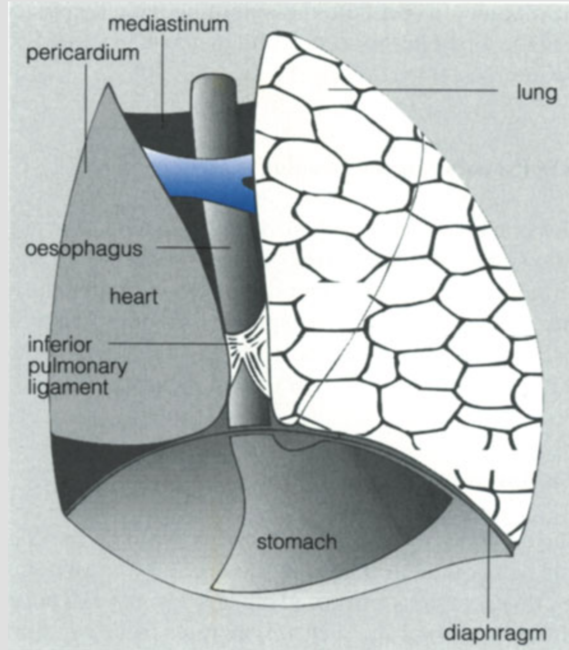


Fig. 11.3. Exposure of the lower oesophagus and OG junction before division of the inferior pulmonary ligament

Cardiomyotomy for Achalasia. The anterior leaf of the exposed phreno-oesophageal membrane has to be divided and dissection continued anteriorly until the OG junction and adjacent lesser curvature of the stomach are visualized.

Tailored Long Oesophageal Myotomy

Dissection of Body of the Oesophagus. After mobilization of the lower oesophagus, further dissection of the gullet proceeds in a cephalad direction with division of the mediastinal pleura medial and parallel to the descending thoracic aorta until the lower limit of the aortic arch is reached (Fig. 11.4). This is best performed with scissors. The inferior pulmonary vein has to be gently mobilized from the oesophagus and retracted medially with the lung parenchyma. Once the mediastinal pleura is divided, further mobilization of the anterior half of the circumference of the oesophagus is needed. For this purpose lifting of the oesophagus from the gutter is achieved by traction on the grasped medial and lateral edges of the cut mediastinal pleura (Fig. 11.4). This is aided when necessary by forward flexion of the flexible endoscope. This stage of the oesophageal mobilization is carried out with a mixture of scissors and pledget swab dissection. A constant di-

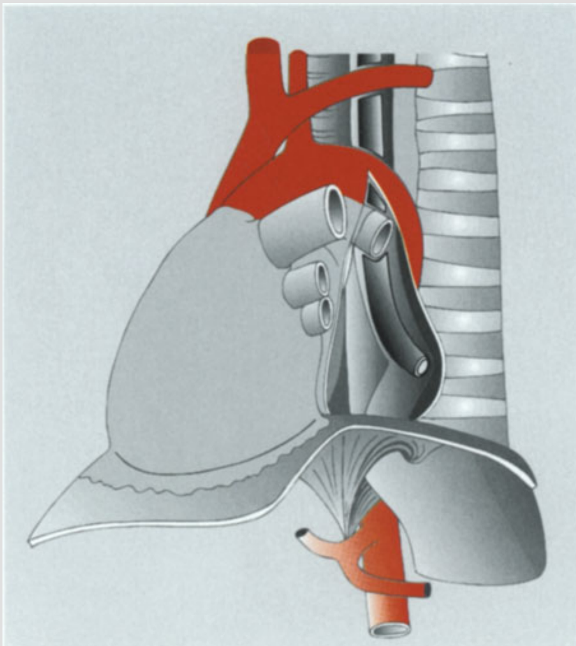


Fig. 11.4. The division of the mediastinal pleura is carried out medial and parallel to the aorta and extends from the hiatus to the aortic arch

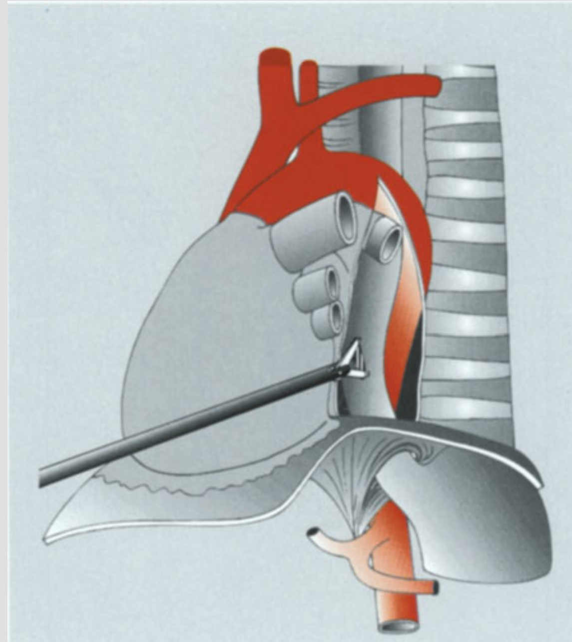


Fig. 11.5. The myotomy is started at the lower end using the twin-action scissors to separate the muscle fibres until the submucosal plane is exposed

rect aortic branch to the oesophagus is encountered just above the inferior pulmonary vein. This vessel is secured by clipping prior to division. The myotomy is commenced in the lower oesophagus. At this stage we consider it safer for the surgeon to resort to monocular vision directly through the telescope. For this reason an image-corrected beam splitter (Storz, Tuttlingen, Germany) is inserted between the telescope and the endocamera. This allows simultaneous direct viewing by the surgeon and television monitoring for the assistant and nurse. There is no doubt that both the resolution and depth perception is incomparably better by direct viewing. This approach is needed to perform the procedure with safety in terms of avoidance of perforation of the oesophageal mucosal tube during the myotomy.

Myotomy. The extent of the longitudinal myotomy is tailored to the extent of the manometric abnormality. It often requires extension to the level of the aortic arch. The myotomy is started at the lower end of the exposed oesophagus using twin-action scissors until the submucosal plane is reached. This is then opened by distraction of the scissor blades (Fig. 11.5). The submucosal plane is then separated from the muscle layers using blunt (closed) scissors dissection. The L-shaped electrosurgical hook is then introduced and

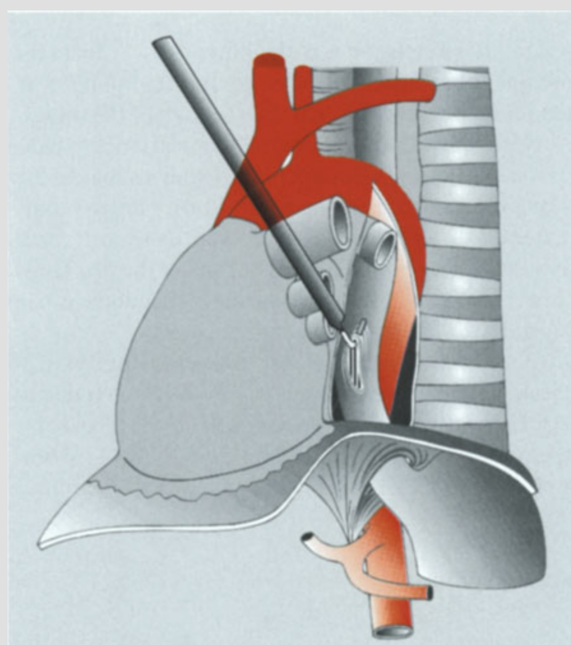
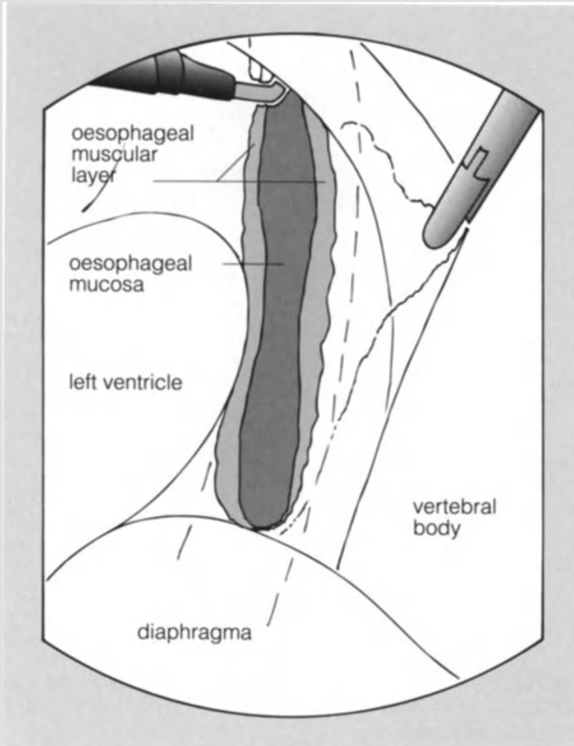


Fig. 11.6. The L-shaped electrosurgical hook is used to lift, stretch and tent the muscles away from the mucosal tube before blender current is applied



a

b

Fig. 11.7 a, b. Completed long oesophageal myotomy. **a** Endophoto; **b** drawing

used to lift, stretch and tent the muscles away from the mucosal tube before blender current (output 35 W, blender setting 2) is applied. The tenting of the muscle layers is crucial since this creates a constriction which, by altering electrical conductivity, localizes the coagulation process to the cut area (Fig. 11.6). The myotomy is extended in a cephalad direction until the aortic arch is reached. Nerves which cross the line of the myotomy are mobilized and lifted up such that the myotomy can proceed without their division.

If the lower oesophageal sphincter is normal, it is left intact; if hypertensive, the myotomy is extended to the OG junction but not across it. The thoracoscopic appearance of a completed long oesophageal myotomy is shown in Fig. 11.7.

Cardiomyotomy

The myotomy is limited to the lower 4.0–5.0 cm of the oesophagus and includes the OG junction and adjacent 1.0 cm of stomach wall (Fig. 11.8). It is commenced in the lower oesophagus as described above using twin-action scissors until the submucosal plane is used. As the OG junction and stomach are reached, the myotomy becomes more exacting technically because the submucosal plane is not as well developed as in the oesophagus. However, with careful dissection and lifting and use of monocular vision, it is feasible to extend the myotomy onto the adjacent stomach wall without mishap. It is preferable to accept a certain amount of oozing from the cut muscle edges than to persist with repeated electrocautery to obtain absolute haemostasis during this stage of the procedure because of the risk of inadvertant mucosal perforation. If oozing does become a problem, control with a pledget swab introduced through the 11.0-mm cannula inside a reducer tube deals effectively with this problem. If the gastric mucosa is accidentally perforated, then a single interrupted suture using 3/0 black silk is used to close the defect.

Insertion of Nasogastric Tube and Indwelling Chest Drain

At the end of the procedure, the endoscope is withdrawn and replaced by a nasogastric tube. This is guid-

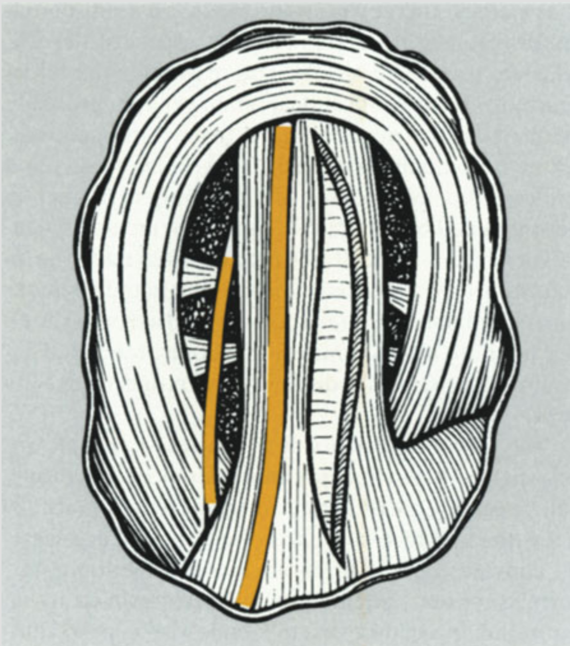


Fig. 11.8. Extent of myotomy for achalasia

Fig. 11.9. Appearance of the chest wall 4 weeks after thoracoscopic myotomy

ed down the oesophagus into the stomach under visual control to eliminate the possibility of perforation of the exposed mucosal tube. The hemithorax is irrigated with warm isotonic Ringer's lactate (38 °C) to clean the aortovertebral gutter. A chest drain is inserted through one of the access cannulae and the lung inflated. Recently we have abandoned the use of a nasogastric tube. Before the flexible endoscope is removed, insufflation of air distends the mucosa and confirms its integrity.

Removal of Cannulae and Closure of Wounds

The cannulae are then removed. The stab wounds are infiltrated with bupivacaine and the edges approximated with subcuticular dexon.

Postoperative Care

The patients are kept in the recovery ward for 6 h and, if stable, are then transferred to the surgical ward. A chest X-ray should demonstrate full lung inflation at this stage. The re-expansion of the lung is rapid and uncomplicated in these patients because there is little mechanical compression of the pulmonary parenchyma during the operation.

The nasogastric tube is removed on the 1st postoperative day and oral fluids started if the second chest film confirms continued full lung expansion and absence of extravasated air or fluid leaks. The chest drain is removed on the same day. If satisfactory progress is maintained, oral feeding is started on the 2nd postoperative day. Pain is usually minimal and consists of chest soreness during the first 12 h. It is managed by intramuscular opiate injections administered as required.

Patients are usually fully ambulant by the 1st postoperative day and are discharged on the 4th day after the operation.

Clinical Results

The series to date is small and consists of 10 patients who underwent tailored oesophageal myotomy (six nutcracker, two diffuse oesophageal spasm), and two underwent cardiomyotomy for achalasia. The appearance of the chest wall at 4 weeks after the procedure is shown in Fig. 11.9. There have been no instances of post-thoracoscopy pain, and recovery was quick with return to full activity by 2–3 weeks.

Symptomatic review at the outpatient clinic during a follow-up period which averages 6 months has confirmed complete relief of non-cardiac chest pain and dysphagia in patients with nutcracker oesophagus and diffuse oesophageal spasm. One patient (a smoker) in this group developed epigastric pain and was found to have duodenal ulceration; he has responded to ranitidine therapy.

Complete relief of dysphagia has been obtained by the achalasia patients who have no dietary restrictions. To date, these patients have not complained of any reflux symptoms. One of the two patients treated for achalasia by thoracoscopic myotomy continued to have some dysphagia. This was due to in complete division of the muscle evats across the gastro-oesophageal junction. We now prefer is perform cardiomytomy through the laparoscopic approach.

Comment

The most common motility disorder responsible for non-cardiac chest pain is the nutcracker oesophagus which is found in 27%–48%. The exact mechanism responsible for the pain remains unknown although the findings of a recent study on the capacity of the oesophageal blood flow to rewarm the oesophagus after a cold challenge are suggestive of ischaemia resulting from the high-amplitude contractions or spasm.

A collective review of the long oesophageal myotomy involving 199 operations from ten reports between 1964 and 1982 showed that this procedure resulted in symptomatic relief in 77% of patients suffering from hypermotility disorders. Nonetheless, this operation is infrequently performed for symptomatic hypermotility disorders despite the generally acknowledged view that medical therapy is unsatisfactory in a substantial cohort of patients, certainly far in excess of the 5% who are treated surgically. The reason for the reluctance to resort to surgical management probably stems from the need for an extensive thoracotomy. There is no doubt that, apart from the morbidity and prolonged convalescence, thoracotomy is frequently accompanied by intractable chest pain including neuralgia which is difficult to treat and often necessitates referral to specialist pain clinics. Restricted shoulder movement due to scapular fixation and a frozen shoulder joint are also common after thoracotomy and account for a significant disability and reduced capacity for work.

The initial experience with the thoracoscopic approach has shown that an extensive tailored myotomy can be achieved with safety and good symptomatic relief with rapid recovery, early discharge and accelerated convalescence. The thoracoscopic myotomy performed on our patients was not accompanied by an antireflux procedure as the endoscopic procedure does not disturb the normal anatomy of the lower oesophagus. Longer follow-up is needed to determine whether reflux with defective clearance is induced by the tailored thoracoscopic myotomy in these patients.

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12 Periviscerаl Endoscopic Oesophagectomy

G. Buess, H. D. Becker, and G. Lenz

Introduction

Carcinoma of the oesophagus is one of the most malignant tumours of the gastrointestinal tract. Patients with this disease have risk factors which mean they withstand major surgery poorly. Typically, surgery requires thoracotomy, resection of the oesophagus and lymph nodes, and mobilization of the stomach by extensive laparotomy. The anastomosis of the prepared stomach to the cervical oesophagus is performed in the neck.

The need for lymph node clearance is controversial. Clinical studies have not shown a clear-cut benefit for this, and the anatomy of the mediastinum does not allow complete resection of all mediastinal lymph nodes.

The thoracoabdominal approach in these frail patients leads to significant postoperative pulmonary complications resulting in high mortality. Several groups interested in minimizing the trauma of the thoracotomy changed to blunt oesophageal dissection. Avoidance of thoracotomy meant that the dissection was performed without visual control.

The aim of decreasing complication rates by using this technique has not been borne out by current reports of results. The reason for this is probably the increased tissue damage of the mediastinum during blind dissection. Using experimental animal studies we have shown major cardiopulmonary and other effects caused by both conventional techniques; on the other hand, endoscopic microsurgical dissection of the oesophagus (EMDO) had much less influence on these parameters.

After the establishment of clinical transanal endoscopic microsurgery (TEM) in 1985, we went on to develop the instrumentation required for EMDO and performed extensive animal studies. This operative technique is called EMDO according to its developers Buess, Kipfmüller, Naruhn and Melzer. Its first clinical application was in 1989, performed by Buess and Becker in Tübingen.

Indications and Preoperative Investigations

Indications

A definite statement of the indication for EMDO is not possible so soon after clinical introduction of the technique. After the successful initial phase, where operations were limited to patients with T1–3 tumours, the indications have now broadened to include tumours of any size and location where preoperative work-up does not show evidence of invasion of vital structures.

Preoperative Investigation

The routine diagnostic work-up includes: barium meal, oesophagoscopy with biopsy, anteroposterior and lateral chest X-ray, computed tomographic scan of the chest and upper abdomen, lung function tests and cardiac assessment. Regarding biochemical investigations, liver function impairment is taken to be of particular importance. In our collective series of patients in Tübingen, portal hypertension on the basis of alcoholism is often seen.

Endoscopic findings should give exact tumour localization and information of its extent. Evidence for perioesophageal infiltration of adjacent organs is not reliably demonstrated by computed tomographic scan. Endoluminal ultrasound is at present unquestionably better at indicating the depth of invasion. This information is of utmost importance for the accurate use of ES. Using mediastinoscopic dissection, the operative exposure is limited, and evaluation by tactile palpation, as in all ES procedures, is not possible.

Preoperative Preparation and Patient Consent

Preoperative Preparation

Smokers are advised to stop smoking. Patients with obstructive airways disease should have intensive preparation with physiotherapy and medical treatment.

Patient Consent

The risk of complications using EMDO is essentially the same as in conventional surgery. In addition, consent for conventional thoracotomy is discussed, as conversion from EMDO may be required in certain situations. Understanding the nature of the conventional procedure, the patients must have stated a preference for EMDO.

Anaesthesia[1]

During preoperative evaluation, carefully watch for dehydration, hypovolaemia, anaemia, hypokalaemia and hypomagnesaemia. Most of the patients are high-risk cases, often with reduced general health, poor nutritional status due to dysphagia and cachectic disease, alcohol dependency with reduced liver function and other related diseases, habitual smoking accompanied by chronic bronchitis and reduced lung function. Patients on total parenteral nutrition may develop intraoperative hypoglycaemia after discontinuation of high-concentration glucose solutions; these patients may also require increased ventilation due to the significantly increased CO_2 production because of lipogenesis, and postoperative weaning from the respirator may be difficult.

Patients with oesophageal diseases tend to regurgitate and aspirate. Special attention is required in cases of obstruction or stricture of the oesophagus when laryngeal reflexes are impaired. An empty stomach is no guarantee of an empty oesophagus! In case of doubt, a large nasogastric tube is inserted and the stomach and oesophagus aspirated before induction of anaesthesia; confer with the surgeon and be careful: there is risk of injury.

Endobronchial (one-lung) anaesthesia, often used in oesophageal resection with laparotomy and right-side thoracotomy, is unnecessary in the case of endoscopic dissection. Access to the patient is, however, considerably reduced in the two-cavity procedure with two operating teams. Almost all of the patient except for the right arm is draped, and access to the nose-mouth area, endotracheal tube and gastric tube is markedly reduced.

General endotracheal anaesthesia is often combined with continuous thoracic epidural anaesthesia which is performed before the induction of general anaesthesia. It is best to treat the patient as a "full-stomach" case and perform a rapid sequence induction with high-capacity suction at hand. Orotracheal intubation is performed with a non-kinking spiral tube. Large-lumen venous cannulae (right forearm in particular), a central venous catheter or Swan-Ganz catheter (right jugular vein in particular) and an arterial cannula (right radial artery) are inserted. After consultation with the surgeon, a large-lumen gastric tube (30 French) is inserted. Bladder catheterization, rectal temperature monitoring, and eye protection are also performed. Pulse oximetry and expiratory CO_2 monitoring should also be performed. Balanced anaesthesia is performed with good muscle relaxation, especially to prevent coughing or pressing during endoscopic dissection.

The close anatomical interrelationships between the endoscopic operative field and major structures (trachea, bifurcation, bronchi, heart, major vessels, parasympathetic fibres) pose the risk of possible complications: reflex bradycardia, arrhythmia, cardiovascular depression, massive problems with mechanical ventilation. Intraoperative tendency to atelectasis is increased by intrathoracic manipulations and intra-abdominal procedures; this leads to pulmonary shunting due to an impaired ventilation: perfusion ratio. Ventilation problems can also result from compression of trachea or bronchi due to leverage from the endoscope during preparation. Most of these problems, however, subside after temporary interruption of extreme endoscopic manipulations; massive haemorrhage and pneumothorax have not occurred in our patients. Postoperatively, the patient is transferred to the intensive care unit. Overnight ventilation is recommended, especially in the presence of pulmonary pathology and weaning problems. Extubation should be performed when the patient is awake and sitting, since postoperatively there may be no barrier against reflux and aspiration. Delirium should be anticipated in alcoholic patients.

[1] The following section was written by G. Lenz.

Patient Positioning, Skin Preparation and Draping

Patient Positioning

The operation is performed simultaneously by two teams of surgeons. The patient is positioned in the following way: using the supine position the thorax is elevated on the right with a 5-cm thick support allowing skin preparation to the posterior axillary line. The head is rotated to the right and fixed in position to the operating table with adhesive surgical tape. This preparation allows both operating teams to work without hindering each other, and rapid conversion to an anterolateral thoracotomy is possible during the mediastinal dissection (Fig. 12.1).

Skin Preparation and Draping

After shaving the operative site, the skin from the symphysis pubis to the chin and laterally to the posterior axillary line is washed with antiseptic solution and covered with sterile adhesive drapes (Fig. 12.2).

Fig. 12.1. Positioning on the operating table. The right thorax is elevated approximately 5 cm, the head turned to the right and secured with adhesive surgical tape

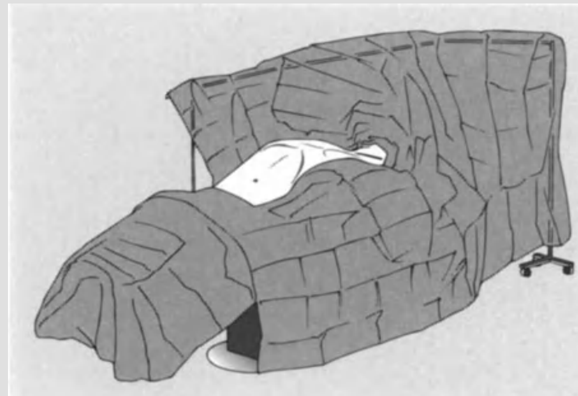


Fig. 12.2. Draping the operative site. Isolation from the anaesthetic area is achieved by a frame covered by drapes

The mediastinal operating team is isolated from the anaesthetic area using a frame covered with sterile drapes allowing access to the left side of the neck.

Layout of Ancillary Instrumentation and Positioning of Staff

Positioning of Staff

The operation is performed simultaneously by the two operating teams. The surgeons performing the gastric mobilization occupy their usual positions, the mediastinal surgeon sits on the left side of the thorax with the assistant standing next to him/her. The mediastinal scrub nurse/technician changes position during the operation: during exposure of the oesophagus via the cervical incision he/she hands instruments to the surgeon and assistant (Fig. 12.3 a). During endoscopic mediastinal dissection he/she stands behind and to the right of the surgeon in order to correctly hand over and remove the long straight instruments (Fig. 12.3b).

Arrangement of Ancillary Instrumentation

Instruments for the mediastinal dissection are arranged on two instrument tables. Conventional instruments are used for the neck exposure. During the mediastinal dissection, the mediastinal instrument table is placed to the left of the surgeon.

The video equipment, xenon light source, and suction and irrigation equipment is placed on a separate bench (we use the TEM unit).

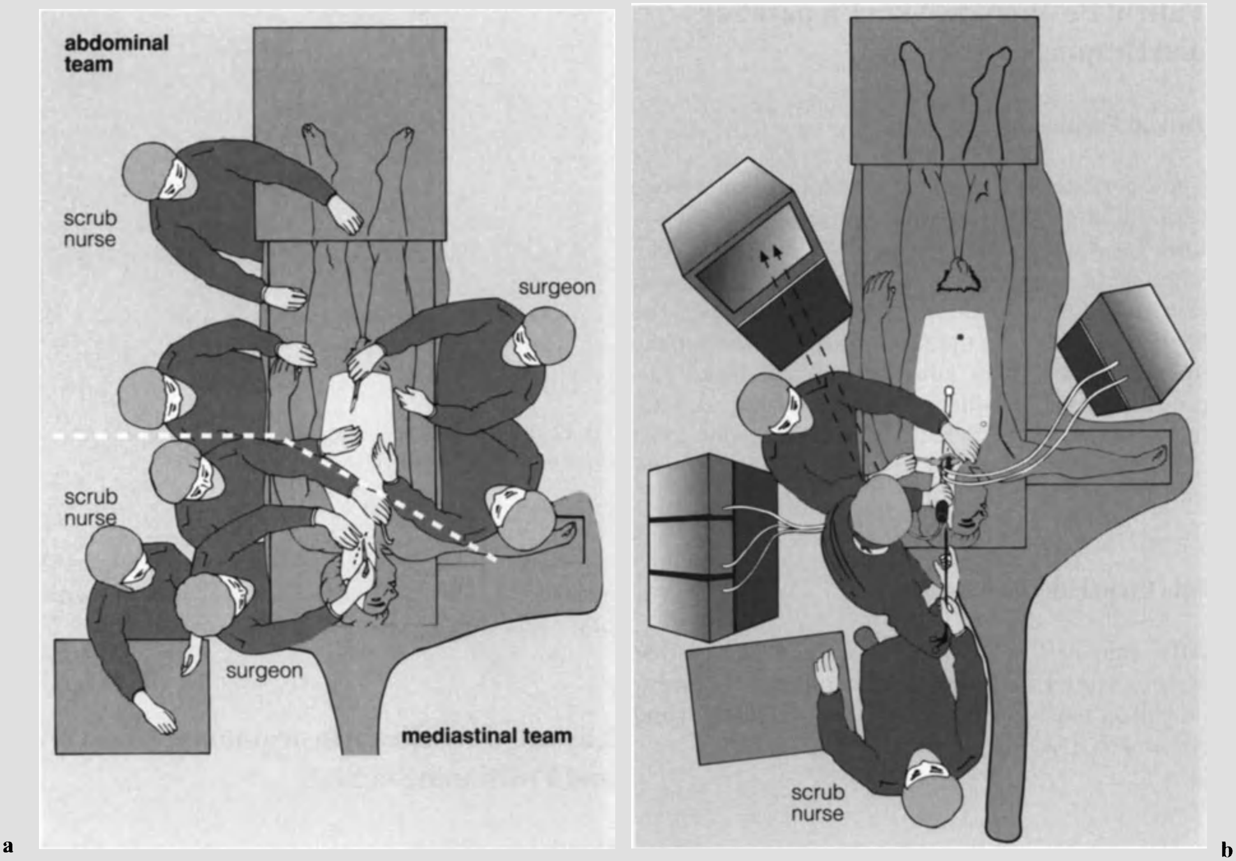


Fig. 12.3 a, b. Positioning of the operating team. **a** During cervical exposure, the scrub nurse stands between the mediastinal surgeons. **b** During the mediastinal dissection, the scrub nurse stands to the right and behind the surgeon. The handover of instruments must be in line with the mediastinoscope

The front lens is cleaned by the assistant using irrigation controlled by a foot pedal. The monopolar diathermy cable used during the mediastinal dissection is simply connected into the classical handle for the conventional exposure of the neck.

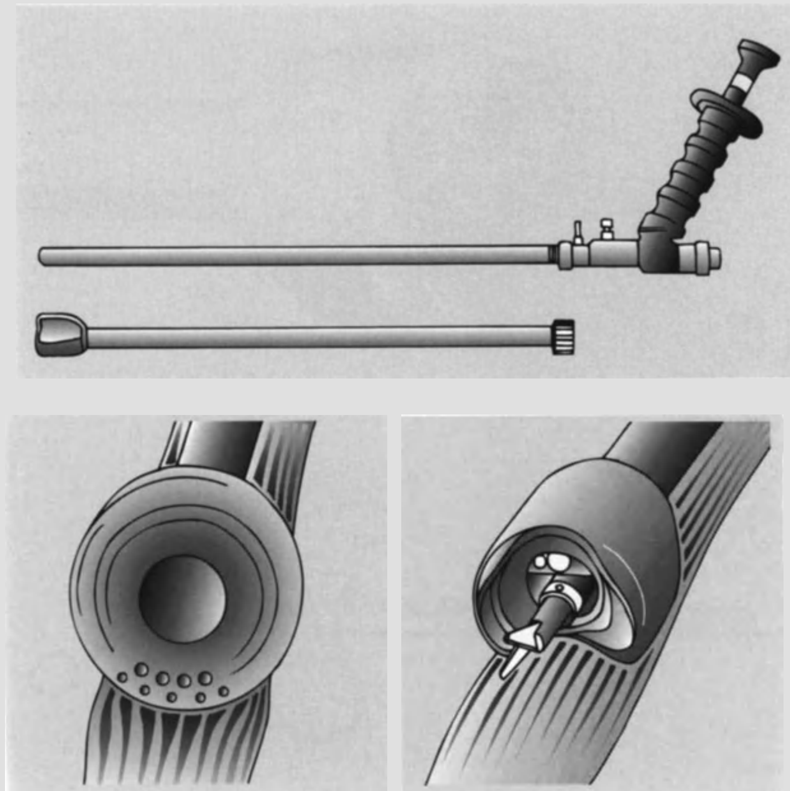
Specific Instrumentation

Operating Mediastinoscope

The space for the endoscopic operation is created by mechanical distraction of tissue planes. Initially space must be prepared by open dissection, and, once enough space for the tip of the mediastinoscope is created, the operation field is exposed by the "olive". To achieve this we have designed a new operating mediastinoscope which has a central working channel and a shaped olive at the tip which exposes the field during the operation (Fig. 12.4 a).

We developed a circular olive during a long phase of experimental operations. In experimental studies, exposure with this olive (Fig. 12.4 b) was very good; however in the small compact mediastinum in humans, a good result could not be obtained. The circular cross-section of the olive resulted in a poor overview of the oesophagus which was pushed too far aside during dissection. We therefore altered the olive's cross-sectional shape in such a way that it occupies much less space, and the grooved region maintains the oesophagus in a central position (Fig. 12.4 c). This olive can be rotated around the endoscope so that the instrument can be moved around the circumference of the oesophagus, keeping it in a stable position during dissection.

Instruments are introduced down the instrument channel of the mediastinoscope. In cross-section the



a

b

c

Fig. 12.4 a–c. The operating mediastinoscope. **a** The operating mediastinoscope showing the angled handle, eyepiece and distal dilating olive. **b** The early circular olive did not allow ideal oesophageal centralization. **c** The final version of the dilating olive makes dissection easier by centralization of the oesophagus

instrument channel measures 8×12 mm (Fig. 12.5). Within the mediastinoscope a lens irrigation system is integrated, allowing its cleaning at any time during the operation.

The forward-viewing *optic* has an opening angle of 72 ° and is a lengthened laparoscopic instrument. The eyepiece end of the optic is angled at 60 °.

Surgical Instruments

Only one instrument can be introduced via the central instrument channel. When any bleeding is revealed by the sucker, the time taken to change instruments could lead to a critical loss of view. This problem is overcome by simple combination of instruments.

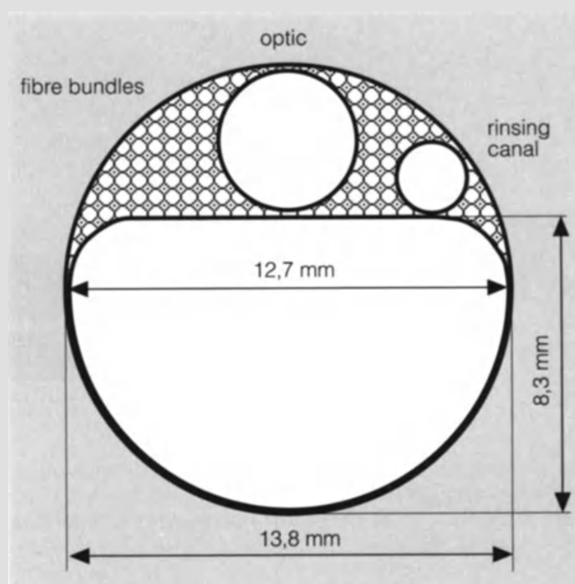
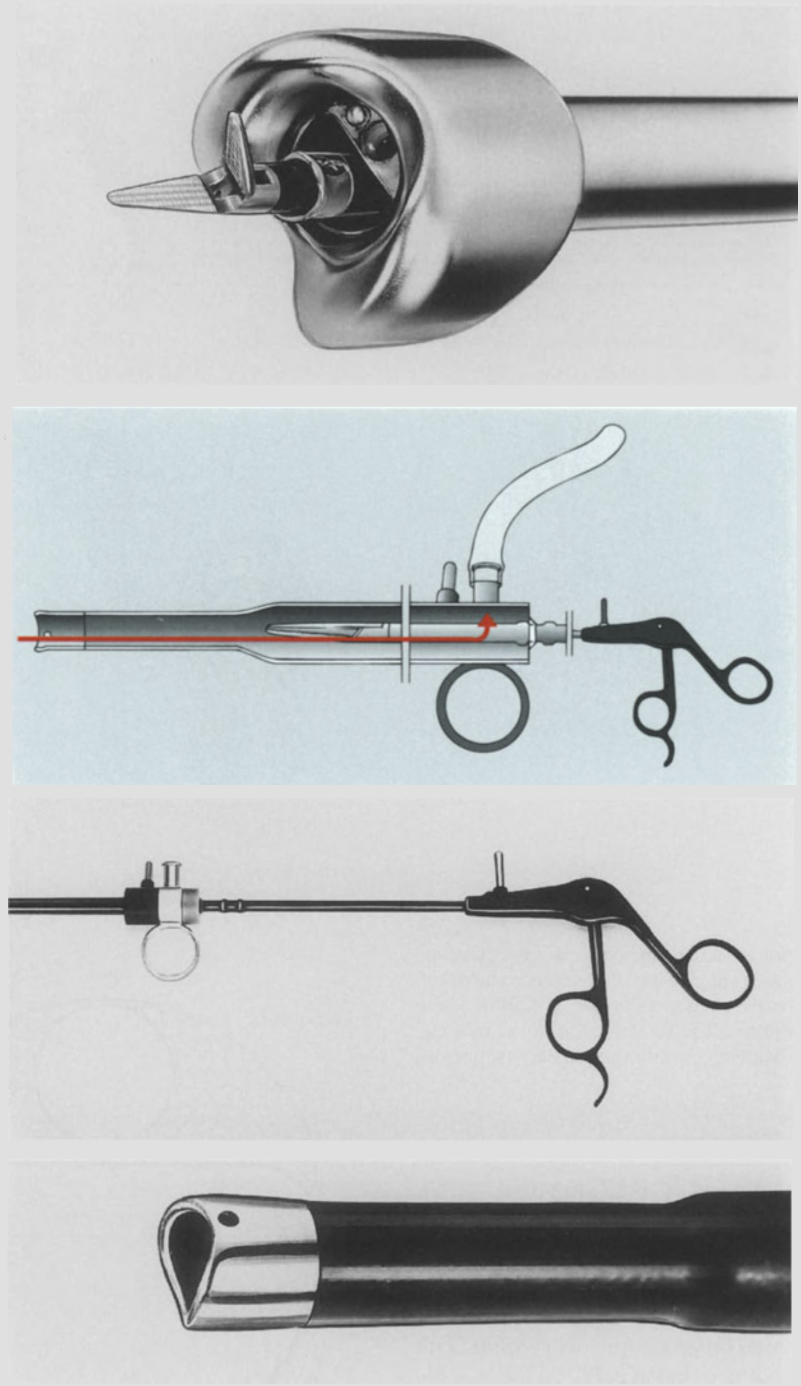


Fig. 12.5. A cross-section of the operating mediastinoscope. The working channel is an incomplete circle



a

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c

d

Fig. 12.6 a–d. The combination sucker. **a** Sucker showing grasping forceps within it. **b** The grasping forceps withdrawn into the wider diameter area. **c** Enlarged view of the ring for the neutral position of the grasping forceps. **d** The tapered shaft of the front piece of the sucker with a non-insulated tip

a

b

c

Fig. 12.7 a–c. The operating instruments. **a** Insulated scissors; **b** insulated forceps for monopolar coagulation; **c** combination sucker

Combination Sucker with Central Instrument Passage

A suction cannula of 8-mm outside diameter (Fig. 12.6a) tapers down at the tip to 5-mm internal diameter. The operating instruments can be introduced down this channel and retracted back within the wider bore segment of the sucker (Fig. 12.6b) if suction and coagulation are required. Small ridges on the central instrument shaft allow it to be steadied by the rubber seal of the sucker (Fig. 12.6c). The avoidance of instrument change-over by this system thus saves time. The non-insulated tip of the sucker is fashioned in such a way that vascular pedicles are centralized during dissection and coagulation (Fig. 12.6d).

Instruments Used Down the Combination Sucker

The *forceps for monopolar coagulation* (Fig. 12.7b) is used to grasp exposed vessels and coagulate them. In addition, it grasps the plastic tube used to pull the transected oesophagus down and the mobilized stomach up for interposition. On the handle is a socket for the attachment of a diathermy cable. The shaft of the forceps is insulated, while the jaws are grooved accurately and have a roughened surface.

The *forceps for bipolar coagulation* is used for coagulation of isolated vessels, especially in those cases where monopolar coagulation could be expected to exacerbate existing cardiac rhythm disturbances. However, to date we have not encountered clinical problems using monopolar high-frequency coagulation.

The jaws of the *scissors* (Fig. 12.7a) are straight and used to cut non-vascular structures or those which have already been coagulated. Using a specially designed Clip applier, vessels can also be clipped.

Steps of the Operation

Simultaneous Procedure

The abdominal and mediastinal operating teams begin simultaneously. Abdominally the stomach is mobilized in preparation for pulling up, as in the conventional procedure. Special attention is paid to maintain a good blood supply to the whole stomach and provide enough mobilization to allow tension-free anastomosis in the neck.

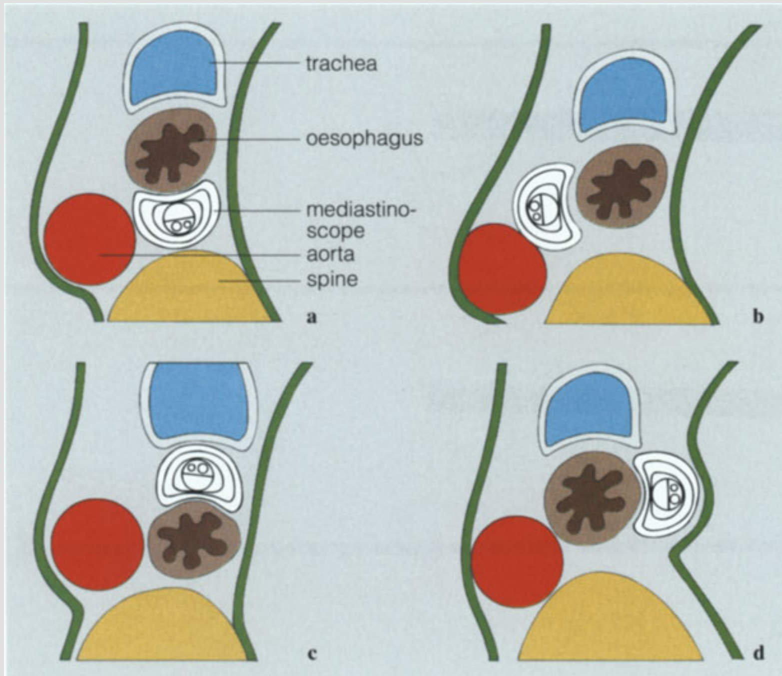


Fig. 12.8 a–d. The landmarks during mediastinal dissection. **a** Posterior, between spine and oesophagus. **b** Endoscope positioned on the left side of the oesophagus with the aorta laterally. **c** Anteriorly, between the oesophagus and trachea. **d** Placed on the right side of the oesophagus, pleura to the right

Mediastinal Dissection in the Tumour-Free Region

Beginning at the suprasternal notch, the skin incision is made for approximately 10 cm along the anterior border of left sternocleidomastoid muscle. Taking care the external jugular vein is not damaged, the strap muscles are divided in the direction of the muscle fibres, and the omohyoid muscle is transected. The lateral thyroid capsule is exposed, and the crossover of the inferior thyroid artery and recurrent laryngeal nerve is displayed. Below this crossover, the oesophagus is exposed by careful blunt dissection from the posterior aspect of the trachea and prevertebral fascia. After dissection around the right side of the oesophagus using a blunt right angle, a silicon sling is placed around the oesophagus.

The oesophageal dissection continues just outside the plane of the longitudinal oesophageal muscle fibres. Using pledget dissection, the loose areolar tissue surrounding the oesophagus is separated revealing vascular structures which are grasped by forceps and diathermied using monopolar coagulation. This dissection is continued for 2–3 cm inferior to the suprasternal notch, creating enough space for the introduction of the operating mediastinoscope.

At this point the change is made from the conventional operating technique to the endoscopic technique. The instrument table with the instruments for endoscopic dissection is correctly positioned and connected to the ancillary instruments (Fig. 12.3 b). The scrub nurse/technician then positions him/herself behind and to the right of the surgeon, allowing optimal handing over and receiving of the endoscopic instruments. The assistant surgeon helps by providing optimal traction on the oesophageal silicon sling, by activating the diathermy and by irrigating the front lens as required using a foot pedal.

Perioesophageal Dissection

Anterior traction on the oesophagus is achieved by the assistant using the silicon sling, thus providing space *posteriorly* for the introduction of the mediastinoscope olive. Initial olive introduction is guided digitally and may be made easier using a small right-angled retractor. At this stage, the groove of the olive is oriented anteriorly and so it partially encircles the posterior oesophagus, centralizing it (Fig. 12.8 a).

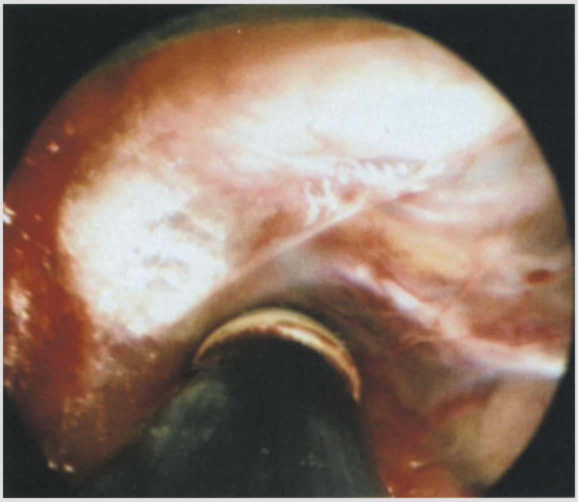


Fig. 12.9. Dissection between oesophagus and trachea. The white cartilages of the trachea in the *upper half* of the image (see Fig. 12.8 c)

With the combination sucker, blunt dissection posterior to the oesophagus is started (Fig. 12.10 a). By careful pushing movements (Figs. 12.10 b, 12.11) of the combination sucker, the loose areolar plane between the oesophagus and surrounding structures is separated, taking care to remain close to the longitudinal oesophageal muscle fibres. Space is created by mechanical distension provided by the olive. Exposure is thus maintained for further dissection (Fig. 12.10 c).

Ongoing dissection displays strands of tougher connective tissue passing obliquely from above into the wall of the oesophagus (Fig. 12.14 b). These tissue bridges may be connective tissue with a suspensory function or vagal branches. Identification as a branch of the vagus is possible if the vagal trunk is exposed.

Those bridges that appear not to contain vessels are placed under traction by forward pressure by the mediastinoscope (Fig. 12.14 a). Muscle fibres will avulse from the oesophagus if these bridges are not initially cut with scissors (Fig. 12.14 b).

If, after blunt separation of the mediastinal areolar, tissue vessels are seen (Fig. 12.10 c), they have to be controlled by coagulation (Fig. 12.12) before division (Figs. 12.10 e, f, 12.13). Experience has shown that vessels greater than 1-mm in diameter require coagulation using grasping forceps (Fig. 12.10 e, 12.12). Using this technique the vessels are first mechanically compressed and then coagulated. Alternatively a clip applier can be used.

The dissection of the *left side* (Fig. 12.8 b) of the oesophagus follows the same principles, but starts again in the neck after repositioning of the olive. The perioesophageal space is dissected by visual orientation of the longitudinal oesophageal muscle fibres. Landmarks to the left are the aortic arch and descending thoracic aorta.

The *anterior dissection* (Fig. 12.8 c, 12.9) again commences from the neck. The olive is introduced between the trachea and the oesophagus with its groove again oriented towards the oesophagus. Landmarks during this dissection include the posterior wall of the trachea and the ridges of the cartilaginous tracheal rings.

The dissection of the upper half of the oesophagus is completed by dissection on the *right side* (Fig. 12.8 d). Keeping the plane of dissection close to the muscle fibres, the azygos vein situated laterally is normally not exposed.

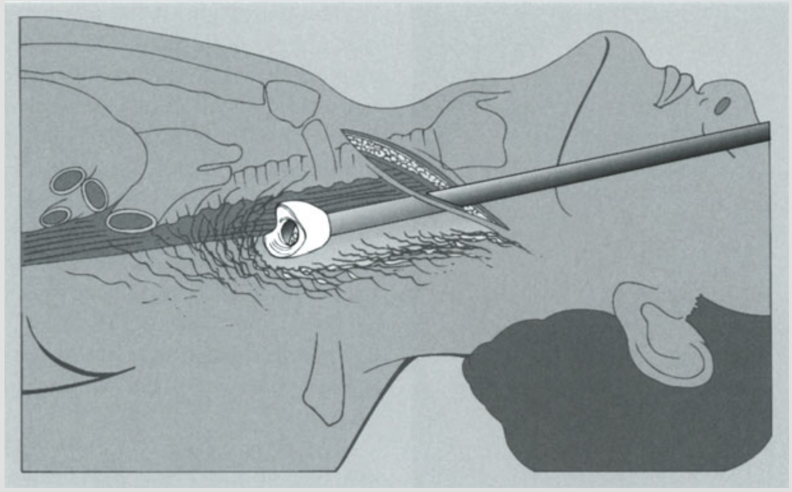
Below the tracheal bifurcation, the movements of the lung surface are clearly visible through the translucent parietal pleura. The thin pleura is often breached during dissection at this point. Providing the mediastinal dissection is haemostatic, pleural drainage is not required.

Dissection in the Region of the Tumour

Prior to the operation, accurate information about the anatomical site and depth of tumour invasion is required by the surgeon. The best available information is provided by endoluminal ultrasound. During dissection around the tumour, fibrous tissue encountered will be more dense. To ensure complete tumour removal, the plane of the muscle fibres can no longer be followed, and a margin of perioesophageal tissue must be resected with the specimen.

If difficulties with orientation occur, further dissection should be continued in another quadrant of the oesophagus. By finding an area without tumour infiltration outside the oesophagus, the plane of dissection can be re-established. Dissection of the oesophagus down one side distal to the tumour facilitates the dissection of the whole tumour-bearing area.

Careful probing of the areolar tissue outside the tumour with the combination sucker helps in identifying the plane of dissection. Further division of adherent fibrous tissue is begun proximally. With advanced tumours, the dense fibrous tissue identified by the sucker has to be divided by scissors. Identifiable vessels within the fibrous tissue are coagulated before division.



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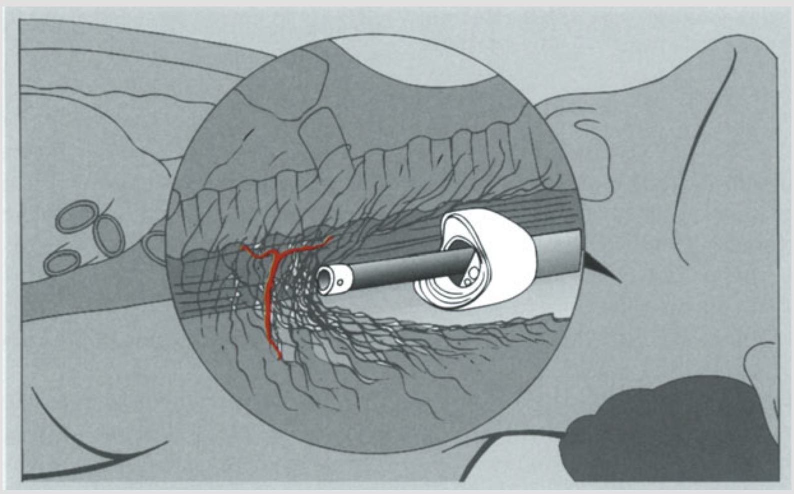

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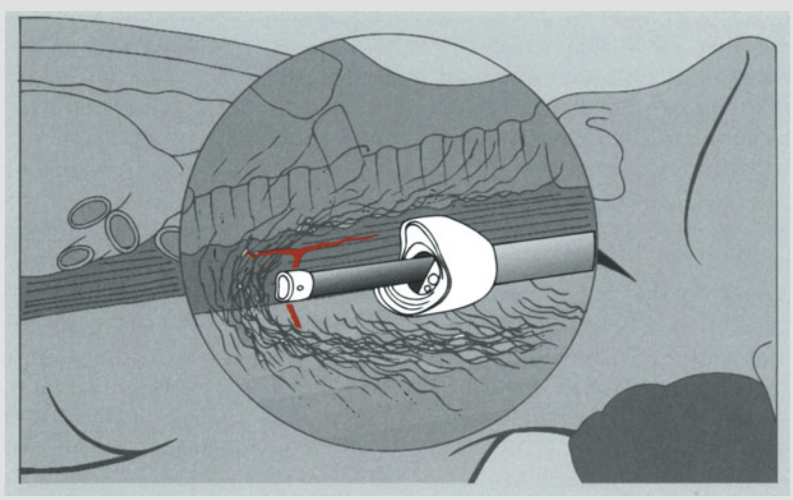
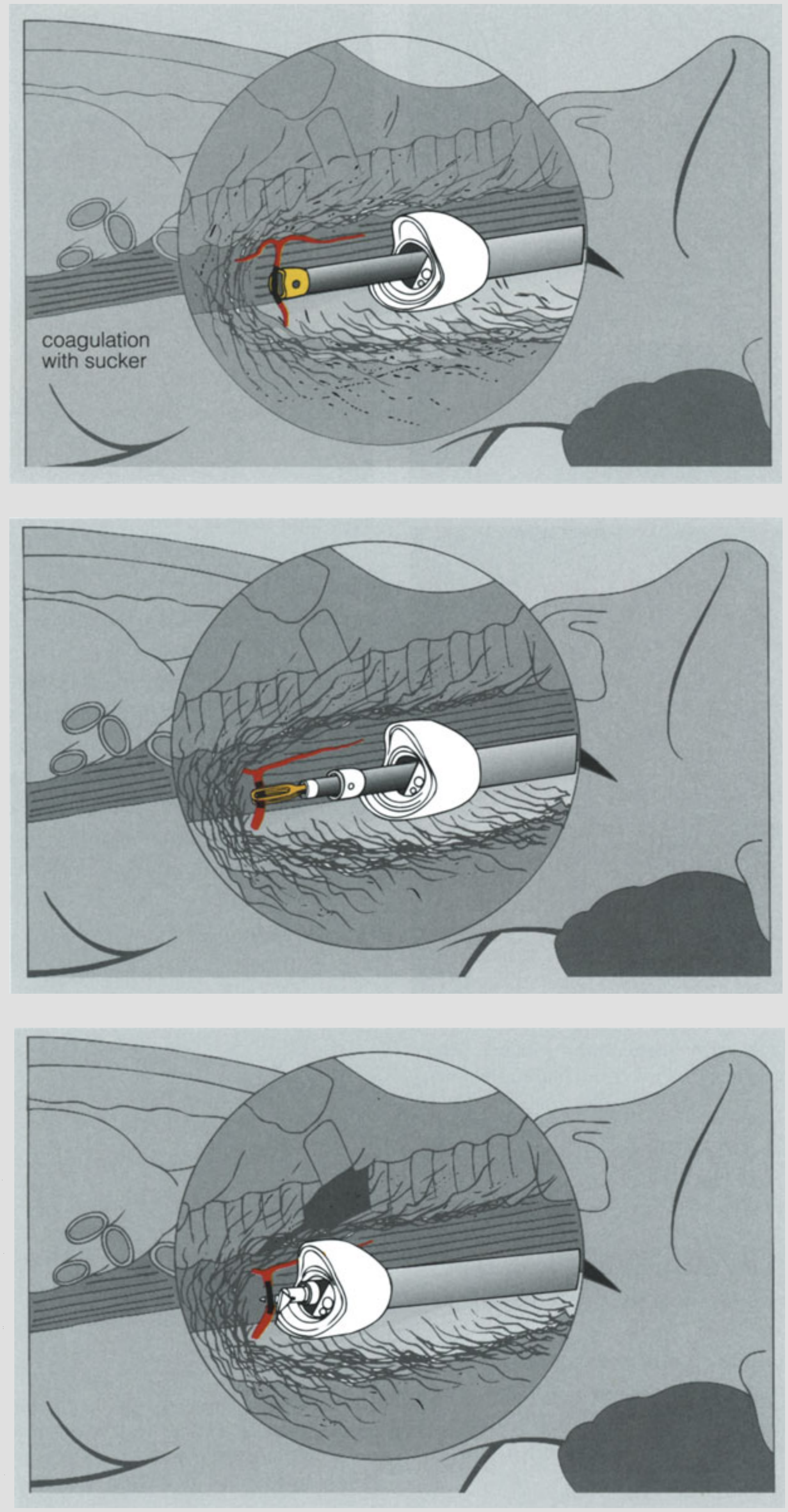


c

Fig. 12.10 a–f. The perioesophageal dissection. **a** An overview showing the olive being placed posterior to the oesophagus. **b** The suction probe is then advanced to the perioesophageal areolar tissue. **c** By careful probing of the perioesophageal areolar tissue, space is created and held apart by the olive

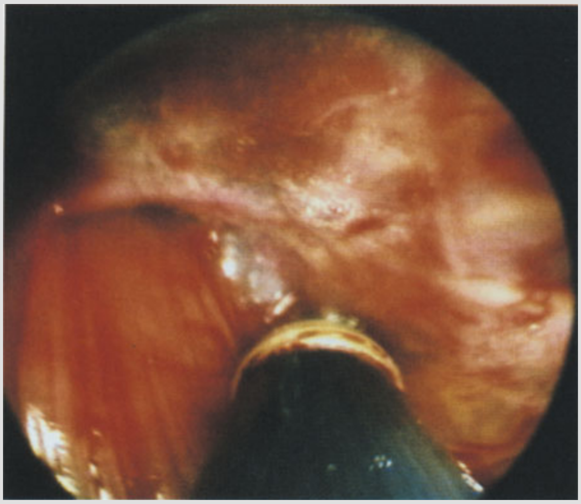


d

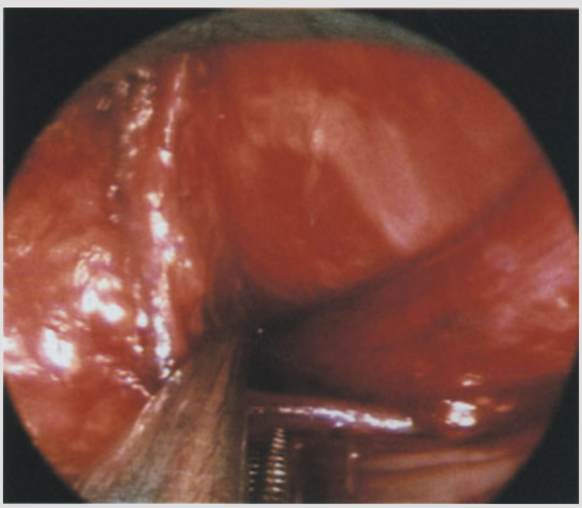
e

f

Fig. 12.10. d Small vessels and areolar tissue connections which may contain vessels are controlled by sucker coagulation. **e** Larger vessels are grasped with insulated forceps and controlled with either monopolar or bipolar coagulation. **f** A coagulated vessel being divided by scissors



12.11



12.12

Fig. 12.11. Dissection of the oesophagus using the sucker. Longitudinal fibres of the oesophagus in the *lower half* of the image (see Fig. 12.10 b)

Fig. 12.12. Vessel is grasped by the monopolar forceps. Oesophagus on the *right side* (see Fig. 12.10 e)

With tumours of the distal third of the oesophagus, tumour dissection is alternately performed by the mediastinal and abdominal surgeons.

The initial abdominal step is to expose the hiatus. With small tumours, blunt dissection upwards may be all that is required, while more advanced tumours may be dissected under vision from below with a right-angled retractor.

Similar to combined synchronous abdominoperineal excision of the rectum, the plane of dissection may be demonstrated from above using the mediastinal combination sucker or olive position. This plane is

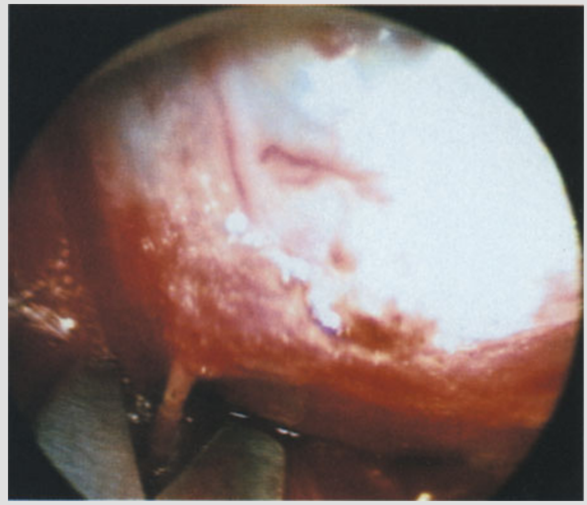
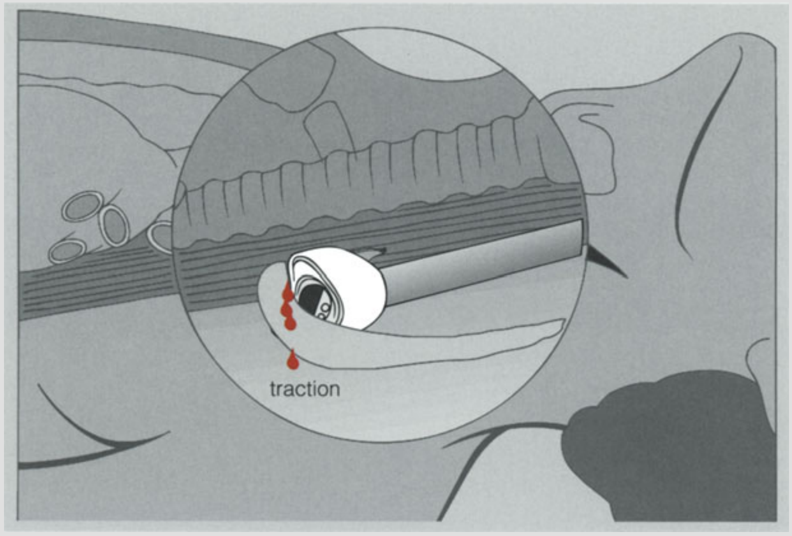


Fig. 12.13. Coagulated vessel is cut by scissors (see Fig. 12.10 f)

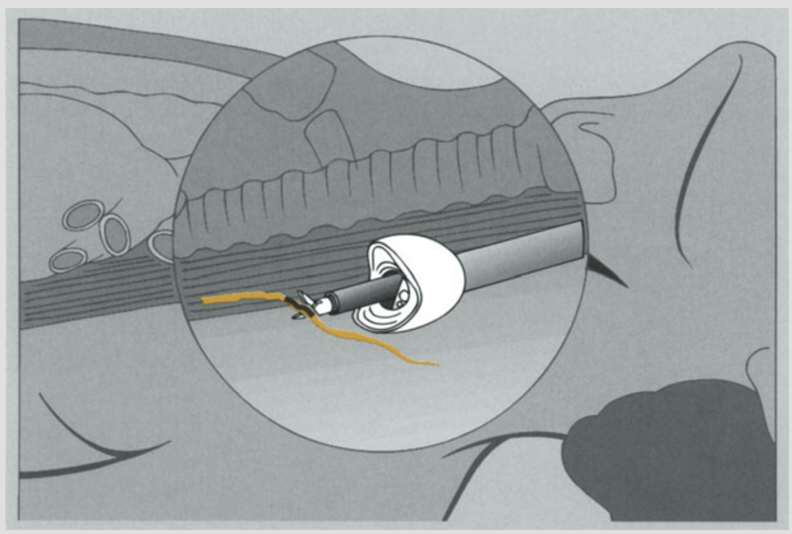
entered from below by the abdominal surgeon's finger (Fig. 12.15). The decision as to who continues further dissection is made on the basis of which surgeon has the best access. With advanced tumours the additional information provided by the abdominal surgeon's digital assessment improves the safety of the mediastinal surgeon's dissection. Digital dissection from below may identify vascular bridges requiring coagulation and division from above. Finally, the remaining tissue bridges can easily be dealt with during the following step of the dissection.

Fig. 12.14 a, b. Dissection of the oblique connecting strands to the oesophagus. **a** Excessive traction on these fibres causes muscle avulsion. Bleeding obscures the view. **b** Early exposure of the oblique connecting strands, followed by coagulation and division

Fig. 12.15. Identification of the plane of dissection behind the tumour by digital contact between the finger of the abdominal surgeon and combination sucker



12.14 a



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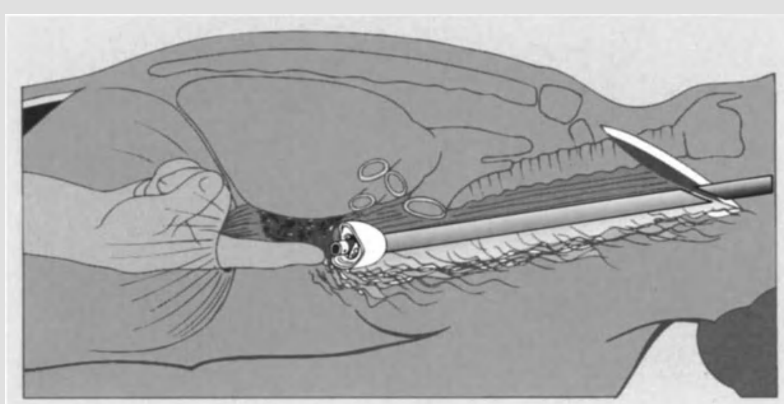
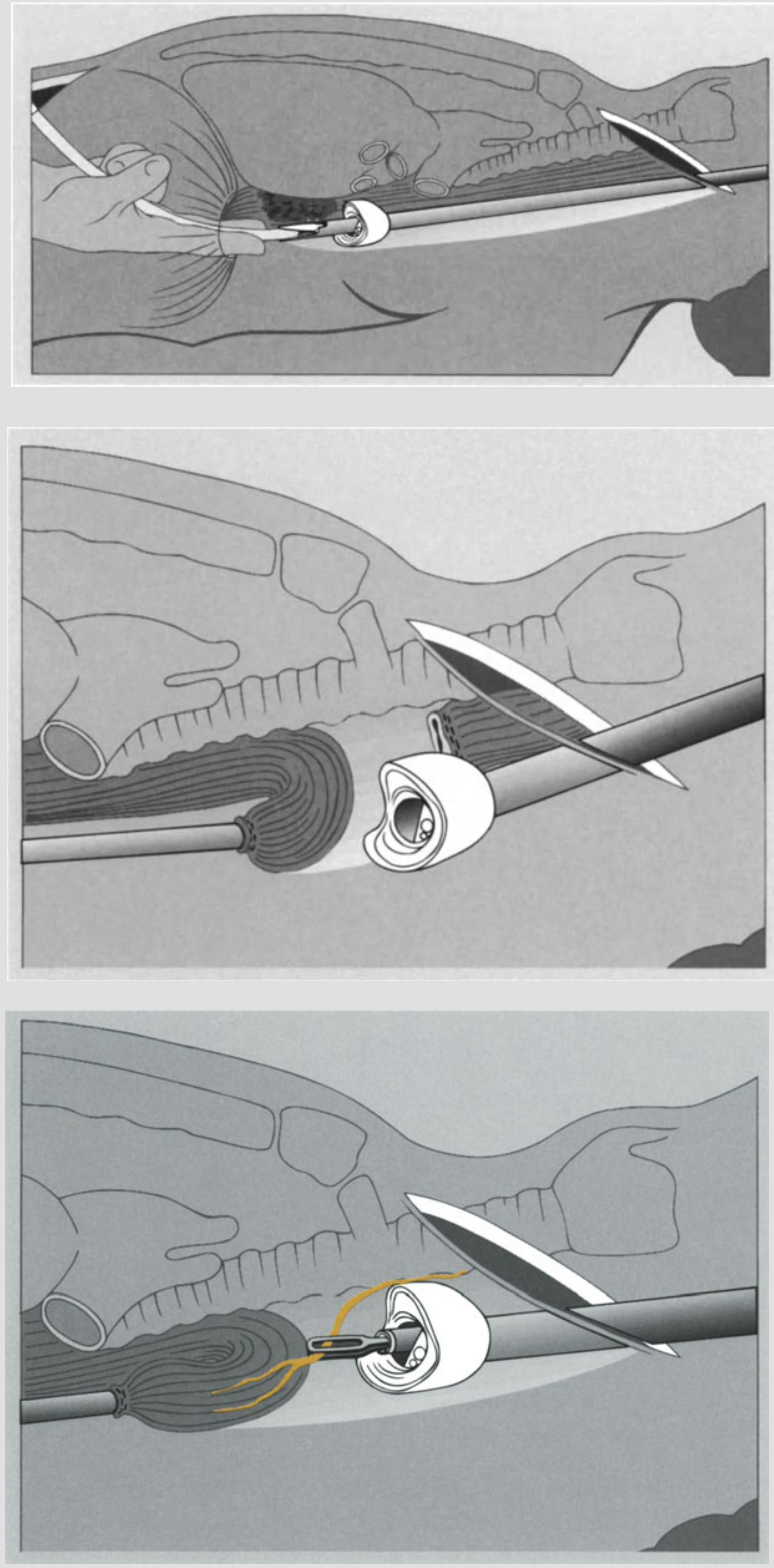


12.15



a

b

c

Fig. 12.16 a–c. Preparation for folding of the oesophagus. **a** Pulling the plastic tube up from the hiatus. **b** After GIA oesophageal transection, the oesophagus is folded over under mediastinoscopic control. **c** Structures still attached to the oesophagus are placed in traction, coagulated and divided

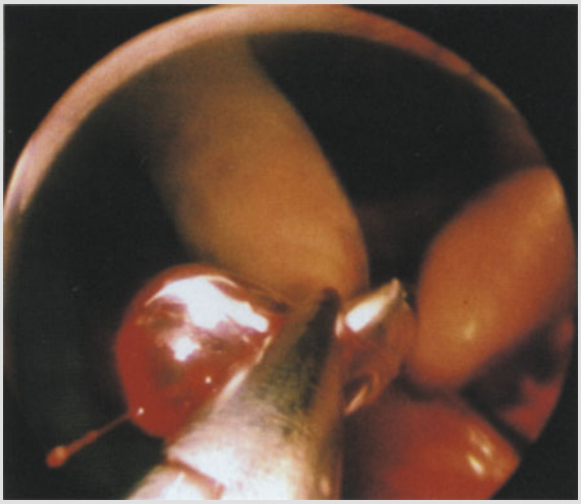


Fig. 12.17. Pulling the plastic tube up from the hiatus, fingers of the abdominal surgeon (see Fig. 12.16 a)

Dissection After Folding of the Oesophagus

Initial preparation is made by advancement of the mediastinoscope to the hiatus. The abdominal surgeon places a plastic tube within the view of the mediastinoscope. Under vision this is grasped by the jaws of grasping forceps and the mediastinoscope is withdrawn to the neck (Fig. 12.16 a, 12.17). The nasogastric tube within the oesophagus is withdrawn by the anaesthetist. Using traction on the silicon sling around the cervical oesophagus, the mediastinal surgeon transects the oesophagus approximately 3 cm distal to the inferior thyroid artery using a GIA stapler. Prior to transection, the mediastinal oesophagus is sutured to the plastic tube with strong suture material.

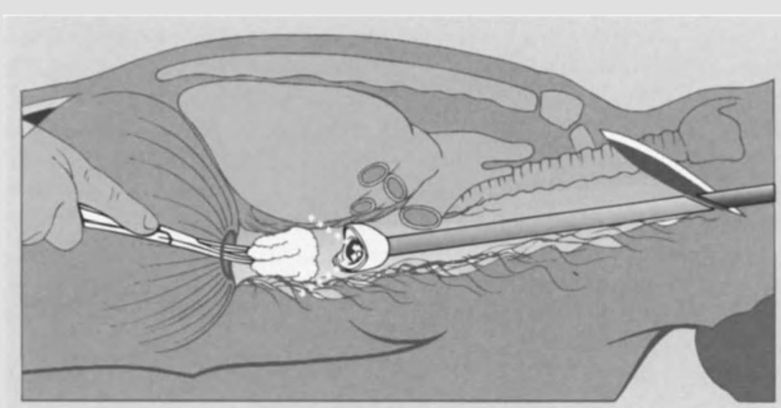
By gently pulling on the plastic tube, the oesophagus folds on itself. The mediastinoscope is inserted to follow this process visually (Fig. 12.16 b). At this stage of the operation, the space available is greater than during perioesophageal dissection and allows a superior view for the mediastinal surgeon. Tension on remaining adherent fibrous connections exerted by the abdominal surgeon allows their easy identification, exposure and division (Fig. 12.16 c). The extraction of the oesophagus down to the hiatus is controlled by the mediastinoscope, and the specimen is removed with a small cuff of stomach. The specimen is then opened, displayed and photographed.

The posterior mediastinum is displayed by the abdominal surgeon inserting a swab mounted on a grasping forceps up to the tracheal bifurcation (Fig. 12.18). By following the swab as it is slowly withdrawn by the mediastinoscope, an optimal view of the oesophageal bed is obtained. Control of bleeding is ensured by coagulation so that at the end of this step definitive haemostasis is attained.

Abdominal Pull-Through and Cervical Anastomosis

With a plastic tube securely sutured to the stomach, the mediastinoscope is used to pull the plastic tube up to the neck. Avoiding twisting of the stomach, it is carefully pulled up through the posterior mediastinum to the neck. With the upper part of the stomach remaining at the suprasternal notch without tension, an anastomosis to the cervical oesophagus is performed

Fig. 12.18. Final control of bleeding within the mediastinum. The exposure is facilitated by a swab mounted on grasping forceps controlled by the abdominal surgeon



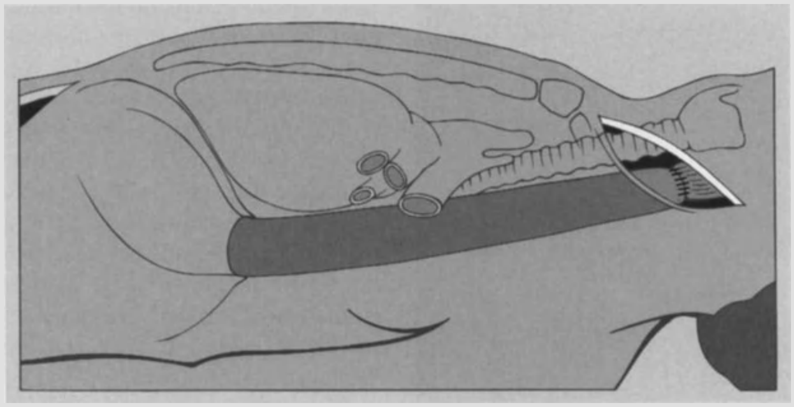


Fig. 12.19. The stomach is pulled to the neck and an end-to-end anastomosis performed

using a two-layered end-to-end technique (Fig. 12.19). On completion, drains are inserted to the cervical anastomosis and subphrenic region.

Postoperative Care

In the early postoperative period monitoring is performed in the intensive care unit. Assisted ventilation is provided for a minimum of 24 h. Daily chest X-rays are performed to identify pleural effusions. Where uncertainty about the presence of a pleural effusion exists, ultrasound examination is performed. Pleural effusions greater than 300 ml have to be drained. Between the 7th and 10th postoperative days, the anastomosis is checked by a Gastrografin swallow, thereafter oral intake commences.

Results

Using the EMDO technique, from September 1989 to October 1990 we operated on 17 patients (15 males and two females) suffering from oesophageal cancer. The average age of the patients was 54.1 years (range, 47–73); mean symptom duration was 4 months. The majority of tumours were located slightly below the level of the aortic arch. Two were located in the upper third, eight in the middle third and seven in the lower third of the oesophagus.

Histologically 15 were squamous cell carcinomas and two adenocarcinomas. The postoperative tumour staging revealed six T1, four T2 and seven T3 tumours. Lymph node status was not determined, as lymph node clearance was not attempted.

The average total operating time was 205 min, 61 of which was the average duration of the endoscopic dissection. In all cases intraoperative blood loss during mediastinal operation was less than 200 ml.

At commencement of clinical application of EMDO, chest tubes were routinely placed when pleura was opened during dissection. As experience was gained, we decided to place the tubes only selectively. Of our last ten patients, only three required pleural drainage when pleural effusions made this necessary in the postoperative period. Thoracic duct leakage occurred in one patient and could be controlled endoscopically without evidence of problems postoperatively. The stomach was anastomosed to the cervical oesophagus in 16 patients, with one having a jejunal interposition.

No intraoperative problem was encountered during mediastinal dissection, but one death occurred postoperatively. This was unrelated to surgery and was caused by complications resulting from a septic thrombosis induced by a central line. This was only discovered at postmortem examination.

Postoperative recovery was marked by better thoracic wall movements and lower analgesic requirement. Phase II-type studies of these benefits in recovery are under way.

Data of long-term survival cannot be evaluated due to the short mean follow-up period.

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Part III: Abdominal Procedures

13 General Principles of Laparoscopic Surgery

A. Cuschieri

Introduction

In this section the steps of various established laparoscopic abdominal procedures are described. All are essentially based on basic surgical skills, the acquisition of which is essential for safe laparoscopic surgery. There is a real risk that in the enthusiasm to embrace this new approach to surgical treatment, surgeons are learning how to perform laparoscopic procedures such as cholecystectomy without acquiring all the basic skills necessary to cover all eventualities. These basic skills are covered in some detail in Chap. 7.

There are some restrictions and difficulties in executing these basic skills of laparoscopic surgery, but these can be overcome by adhering to certain principles which facilitate the execution of laparoscopic procedures. In this chapter, the nature of these problems are outlined, and techniques and precautions are decribed which the author has found to be useful in terms of the safe and efficient execution of laparoscopic operations.

Problems Inherent to Laparoscopic Surgery

An appreciation of the nature of these problems helps surgeons to modify or adapt their technique to enable them to achieve the necessary level of proficiency and safety. The important restrictions encountered in laparoscopic surgery are as follows.

Depth Perception and Instrument Coordination

The first and major problem concerns the image of the operative field, whether viewed by direct monocular vision or from a television monitor. In either instance, the resulting two-dimensional image creates problems with hand-eye coordination and depth perception to the surgeon. However, depth perception and resolution are better with direct monocular vision. It is true that with practice and care, both estimation of depth and accurate instrument coordination are mastered. In this process certain adjustments are necessary which after a while become automatic:

1. Surgeons must resist the habit of looking at their hands when viewing the monitor.
2. The appropriate anatomical reference points to guide the tip of the instrument to its target must be picked. The direction of the cannula is maintained by the assistant during withdrawal or re-insertion of instruments. This permits automatic homing of the instrument tip to the target area without risk of injury to organs or entanglement in adjacent structures, thereby avoiding the need for constant withdrawal of the optic to view the instrument insertion without compromise of safety.
3. Instrument manipulation is easy when the surgeon works close-up with the operating tip of the instrument ahead of the optic, and extremely difficult when the instrument faces the optic as the orientation of the image is reversed.

Anatomy

Undoubtedly the view of the operative field is better than that encountered in open surgery. However, the size of the anatomical structures is altered, and this varies in accordance with their distance from the viewing telescope: the shorter the distance, the greater the magnification. This may pose problems with identification of certain structures, especially when viewed across the television monitor. When doubt exists, the surgeon should detach the endocamera from the telescope and resort to direct monocular vision until the true nature of the suspect anatomy has been established. If measurement of actual size is considered necessary, this is best achieved by reference to a graduated probe introduced for this purpose. Another problem results from the vasodilatation induced by the CO_2. At times this imparts an "inflamed" shiny appearance to the tissues and organs.

Restricted Instrument Mobility

The movement of instruments used for dissection and tissue approximation is limited by the attachment of the cannulae to the abdominal wall. The mobility possible is that which can be obtained around a fixed point and, in essence, is outlined by a cone. Thus cannulae placement for optimal use of the operating instruments relevant to the intended task is crucial. Untold difficulties in the execution of surgical dissection, ligation and suturing will be encountered if the respective positions of the cannulae are such that the instruments when introduced are:

1. Too close, or worse still parallel, to each other
2. Too near the optic
3. Too close to the operating field

The guidelines which the author has found useful for the placement of the accessory instrument cannulae are:

1. Ensure a safe distance between cannulae to avoid crowding and entanglement. This distance must not be less than 5.0 cm.
2. The two operating cannulae (used to execute the intended task) must be positioned within the operative field so as to ensure that the ends of the instruments meet at a 90° angle to each other. The ideal distance from site of entry into the abdominal wall from the operative field should equal half the length of the instruments used for dissection and tissue approximation. This is based on the balance principle where force at either side is equal if the fulcrum is in the centre.
3. The third cannula is sited primarily with a view to optimal retraction.
4. A fourth cannula may be needed for special tasks, e.g. taking up the suture slack during continuous suturing, insertion of slings, onset of complication such as bleeding, etc.
5. All cannulae are inserted under direct vision after establishing the right position by the finger depression test.
6. The appropriately sized cannulae are used in the right place. Usually at least one of the operating cannulae is an 11.0-mm one (essential for pledget dissection and insertion of clip applicator). It is important to determine the optimal site of this large cannula. If, during the course of the operation, a further large cannula is needed instead of one of the 5.5-mm cannulae, this can be replaced quickly by use of the dilating system (Fig. 13.1).
7. Meticulous maintenance of re-usable trocars and cannulae to ensure perfect valve function and seal (washers) is crucial to safe complex manipulations, including difficult or complex dissections and suturing.

Disposable Versus Non-disposable Cannulae

The non-disposable metal trocar and cannulae can be obtained with one of two configurations of the trocar tip: pyramidal cutting or conical. Although the former needs less force for introduction because of its cutting edges, we prefer to use the smooth conical variety since this minimizes vascular damage and haematoma formation when the tip is negotiated through the parietes. The conical trocar should also be hollow internally and have a perforation near the tip so that gas escapes giving rise to an easily audible hiss when the trocar penetrates the parietal peritoneum. This is an important safety feature and signifies that no further advancement of the trocar is needed. At this stage the trocar is removed before the cannula is advanced further into the peritoneal cavity.

The tip of the cannula can be straight or bevelled. The latter is preferable because it can be advanced through the parietes with greater ease. This is important when the visually guided system of cannula introduction is needed, e.g. previously operated patients and in thoracoscopic surgery (see Chap. 7). Provided that they are well maintained, non-disposable trocars and cannulae have a long working life. It is the author's practice to use them except for the first cannula. Since this is the most dangerous step of laparoscopic surgery (unless the open technique is used), the use of a sheathed disposable cannula is sensible.

There is no doubt that there are advantages to the use of disposable cannulae. The disposable item is always pristine, and problems with valve malfunction are obviated. The spring-loaded sheath system which automatically covers the sharp trocar point when the abdominal wall is penetrated adds a certain measure of safety against trauma to internal organs during insertion. It does not, however, abolish completely the risk of accidental trauma to the internal organs during insertion of these cannulae. Although undoubtedly safer in this respect than the metal ones, visceral injury caused by disposable trocars and cannulae can occur and is well documented. The explanation for this is related to the "sheath drag" which is influenced by two factors: the distance between the trocar point and the

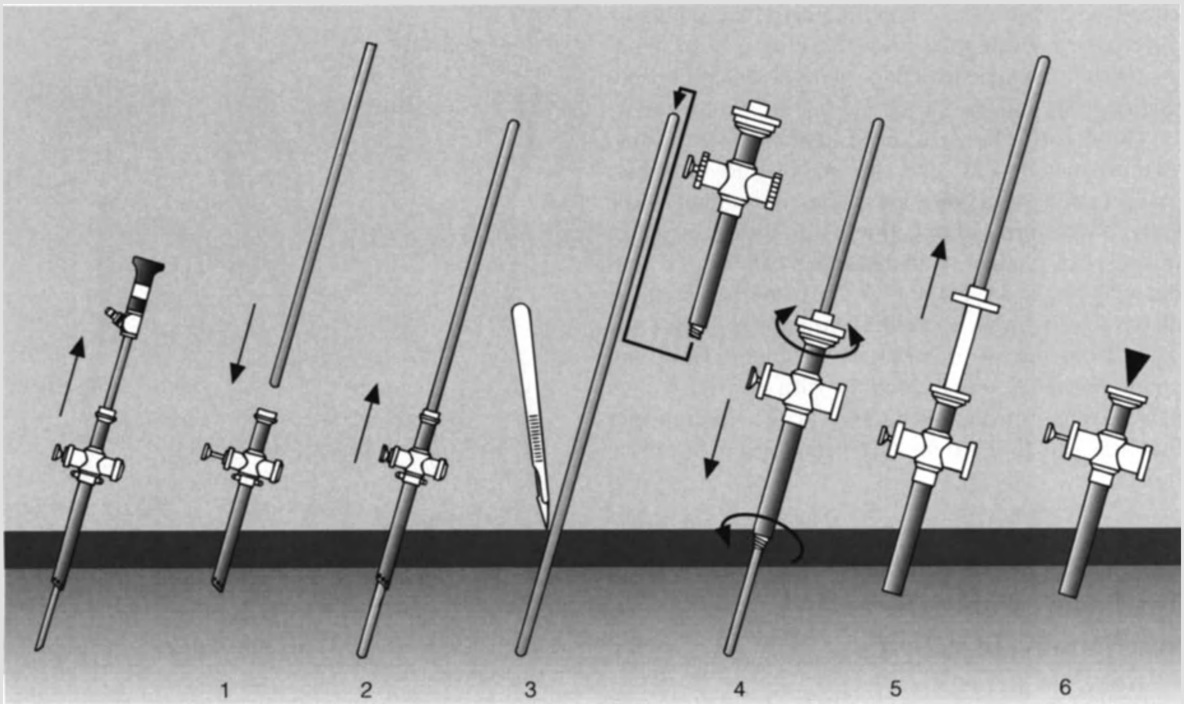
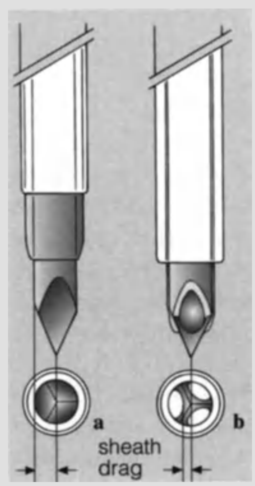
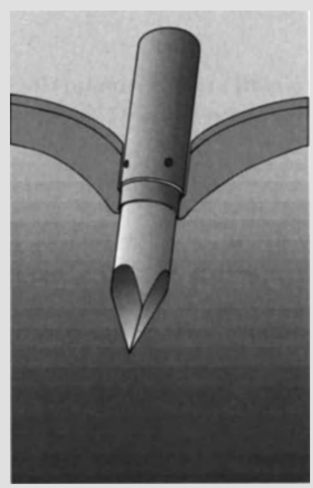


Fig. 13.1. Dilating system for replacing a 5.5-mm cannula with an 11.0-mm one. The instruments needed are a 5.0-mm rod and dilating tube (10.0 mm). *1* The metal rod is inserted in the 5.5-mm cannula and the dilating tube inside the 11.0-mm cannula. *2* The 5.5-mm cannula is removed over the rod and the dilating tube/11.0-mm cannula inserted over the rod which acts as a guide to the peritoneal cavity. *3* This assembly is threaded through the abdominal wall using a rotational threading movement. *4* The process is conducted under visual control by the endocamera. *5* The metal rod is removed. *6* Large cannula in situ





13.2, 13.3

Fig. 13.2 a, b. The distance between the perimeter of the protective outer sheath and the sharp point of the trocar determines the degree of sheath drag. **a** Autosuture trocar; **b** Ethicon trocar

Fig. 13.3. Sheath drag which may lead to visceral injury

rim of the sheath (Fig. 13.2) and the resistance or thickness of the abdominal wall. If the distance between the trocar point and the sheath is significant, the sheath is held back by a resistant or obese abdominal wall allowing the trocar to penetrate to its fullest extent uncovered. This, together with the inevitable depression of the abdominal wall, approximates the trocar point to underlying organs which may be injured before the sheath drag is overcome (Fig. 13.3). The ideal protective spring-loaded sheath should conform to the trocar and for this reason requires to be split.

The use of disposable (AutoSuture or Ethicon) cannulae ensures smooth insertion and withdrawal of instruments and abolishes the problem of gas leaks due to sticking of the trumpet valve. Another problem which is encountered with the non-disposable cannulae incorporating a trumpet valve is the need to depress the valve to move the instrument within the cannula. This is rather frustrating, may lead to "stabbing" or accidental removal of the cannulae during withdrawal of the instrument. The latter problem is also encountered with the disposable cannulae unless an outer fixing screw tube (AutoSuture) is used. Non-disposable cannulae with flap valves obviate this problem.

The disadvantages of disposable cannulae (5 and 10 mm) include cost and the inability to introduce pledget swabs with safety since these are caught by the valve on withdrawal and thus risk dislodgement. In this respect, pledget swab dissection can only be conducted with the use of the 11.0-mm cannulae (metal or disposable) with an appendix extractor to isolate the valve from the swab passage. Meticulous care and maintenance of metal cannula with respect to the valve mechanism and washers is crucial to their proper function and thus safety of the laparoscopic operations.

Safe Creation of Pneumoperitoneum and Laparoscopic Trocar and Cannula Insertion

There is no doubt that the most dangerous steps of any laparoscopic procedure are insertion of the Veress needle and insertion of the first large trocar and cannula for the optic.

Creation of Pneumoperitoneum in the Previously Unoperated Abdomen

The equipment necessary consists of a Veress needle connected to a modern high-flow electronic CO_2 insufflator which is capable of variable flow rates of up to 10 litres/min and allows preselection of the intra-abdominal pressure (see Chap. 2). Optimal exposure is obtained with a constant pneumoperitoneum of 10–15 mmHg.

The Veress needle is most often inserted at the subumbilical site where the laparoscope trocar and cannula will be sited. However, no hesitation should be felt in choosing a different site if adhesions are suspected (see below). Before the needle is inserted, the depth from the abdominal wall to the aorta should be assessed by finger depression (palpation test). Particularly in thin individuals, this can extend to only a few centimetres. The needle is grasped by the stem (Fig. 13.4) not more than 3.0 cm from the tip and introduced through a small skin stab wound by a "feeding" technique through the various layers of the parietes using pressure from the wrist only. Often the click of the spring-loaded safety mechanism is heard when the posterior rectus sheath and peritoneum are breached.

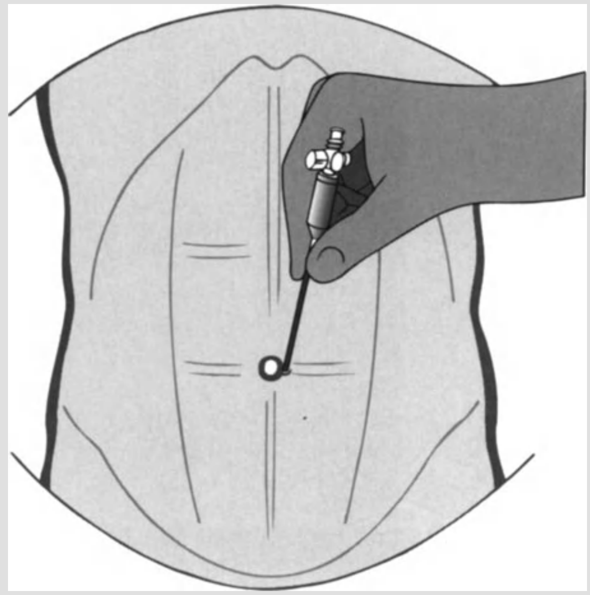


Fig. 13.4. Technique of insertion of the Veress needle favoured by the author. The needle is held by the stem and "threaded" through the parieties

The direction preferred by the author when the subumbilical route is used is upwards and to the right beyond the aortic boundaries, but this is a matter of individual choice.

There are a variety of tests used to ensure that the needle tip is lying free in the peritoneal space, but the important ones are the saline injection/aspiration test and monitoring of the early insufflation pressure and flow rates by the electronic insufflator. In the syringe aspiration test, saline is instilled into the peritoneal cavity. As this flows away from the needle it cannot be aspirated back if the tip is free. Following this test, the needle is attached to the gas inflow tube from the insufflator with the pressure set at 12–15 mmHg and flow at minimum (1.0 litre). If the needle tip is free, the static intra-abdominal pressure should not exceed 3.0 mmHg and rise gradually to reach the preset value. Incorrect positioning of the needle tip is evident if the early pressure is high and the flow is low, when repositioning is necessary. Some of the newer-generation electronic insufflators emit an audible signal to indicate that a correct free position of the needle tip has been achieved. Throughout the insufflation process, periodic percussion of the abdominal quadrants is performed to ensure that the insufflation is total and not confined to one region.

It is important not to insufflate rapidly as this may cause cardiac arrythmias. In this context, the safest practice is to establish the pneumoperitoneum to the desired level of pressure before switching the machine to the high-flow setting. If at any stage cardiac arrythmias including bradycardia or hypotension are encountered, partial desufflation is undertaken and gas inflow is stopped until the patient has stabilized. In this situation it is, however, extremely important to retain enough of a pneumoperitoneum to maintain an adequate view of the peritoneal cavity (see below).

Creation of a Pneumoperitoneum in a Scarred Abdomen

Special measures are needeed in these patients to avoid the risk of injury to adherent bowel. In this context, the important adhesions are those which bind organs to the anterior abdominal wall. These can now be detected by ultrasound examination, and this investigation is highly desirable in these patients as an experienced ultrasonographer can indicate the precise position where the Veress needle can be inserted with safety. The test depends on the measurement of the visceral slide with respiratory movements and with abdominal wall ballottement. The abdomen is scanned horizontally and vertically by a 7.5-MHz probe to identify and measure the movement (slide) of the air-containing organs against the parietal peritoneal line. Adherent bowel is identified by absent or diminished slide. The ultrasound examination may be carried out preoperatively or after induction of anaesthesia depending on local facilities.

In addition, there are certain precautions and measures which need to be adopted in these patients. The first is obvious: the needle should be inserted at least 5.0 cm away from any scar and preferably in a quadrant away from the scarred region. This is particularly important if the ultrasound visceral slide test cannot be performed. The tests to ensure adequate free positioning of the needle tip in the peritoneal cavity must be carried out without fail in these patients, and repeated percussion is performed during the insufflation to ensure uniform distension of the abdomen.

Difficulties may occasionally arise despite the above protocol. In these situations, further attempts to insert the Veress needle should be abandoned and open laparoscopy resorted to, preferably using the modified Hasson's cannula (see below).

Insertion of Laparoscopic Cannula in the Previously Unoperated Abdomen

The most common site for the insertion of the 11.0-mm cannula is the subumbilical region. The author now uses a disposable 11.0-mm cannula in preference to the metal equivalent to increase the safety margin. This large cannula size is preferable to the next size down (10.5 mm) as it allows a better flow rate of gas when the 10.0-mm optic is inserted. However, it needs to be used together with a 10.5-mm reducer as otherwise gas leaks around the telescope.

There are two methods of insertion of this cannula: the direct and the Z-route. The latter entails the advancement of the trocar and cannula through an initial subcutaneous path before the direction is changed and the rectus abdominis and its sheath negotiated. The advantages of this technique include the avoidance of the linea alba and the creation of a flap closure once the cannula is withdrawn resulting in a stronger wound. However, extraction of organs such as the gallbladder is more difficult with this technique which is less popular than the direct route.

Whatever method is used, careful attention to detail and technique is essential. An adequate incision of the skin and subcutaneous tissue commensurate with the size of the cannula is needed. The trocar and cannula assembly (metal or disposable) is held in the right hand, with the butt of the trocar firmly pressed against the palm and the index finger alongside the long axis of the shaft 3.0 cm away from the tip (Fig. 13.5).

The periumbilical region is pulled firmly up by the left hand so that the abdominal wall is tended upwards and the trocar and cannula introduced through the

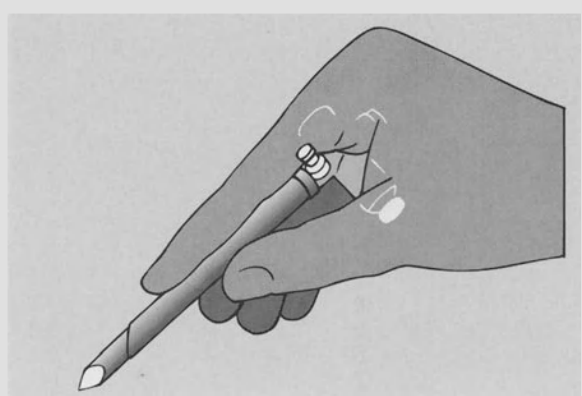


Fig. 13.5. Safe technique for introduction of the laparoscopic trocar cannula. Pressure is exerted from the wrist as the trocar point is reamed through the abdominal wall. The index finger acts as a safety stop

subumbilical incision parallel to the axis of the aorta pointing to the centre of the pelvis. Alternatively, two strong Littlewood's forceps are applied to the edges of the skin wound and the abdominal wall pulled up by traction exerted on the forceps by the assistant. Pressure from the wrist accompanied by a to-and-fro rotational movement is used to gradually "ream" the trocar and cannula through the parietes. Pressure on the butt of the trocar against the palm of the hand prevents riding of the trocar inside the cannula as it encounters resistance provided by the abdominal wall. The tip of the index finger against the shaft of the assembly acts as a safety stop in case of sudden give. The perforation near the tip of the (non-disposable) trocar leads to a sudden escape of gas with a resultant audible hiss as soon as complete penetration of the abdominal wall is achieved. When this happens, the trocar is withdrawn before the cannula is advanced further. The gas line is then connected to the side port of the cannula and the port opened to maintain gas inflow.

Insertion of the Laparoscopic Cannula in the Scarred Abdomen

There are two complementary techniques which ensure safety of cannula insertion in patients with a scarred abdomen once the pneumoperitoneum has been induced. The first is the sounding test for adhesions (Fig. 13.6). A 12-cm long fine needle attached to a saline-filled syringe is introduced perpendicularly through the abdominal wall in the region where the trocar and cannula insertion is envisaged. As the needle is advanced, gas is slowly aspirated and should be identified as constant bubbling through the saline in the barrel of the syringe. The bubbling will stop when the needle tip touches any tissue. The level of the needle at the skin surface when bubbling stops is marked simply by grasping the shaft beween the forefinger and thumb of the left hand. The needle is then withdrawn when bubbling recommences but ceases again when the anterior abdominal wall is reached. This distance equates to the depth of the free space available for safe insertion. By repeating the process at various angles to the horizontal over an entire circle, a good mental picture of the extent of the CO_2 cushion underneath the intended trocar and cannula insertion site is obtained. In these patients an extra safety precaution consists in the initial insertion of a 5.5-mm cannula. Once the surgeon is satisfied with the position and absence of iatrogenic damage by inspection through a 4.0–5.0-mm telescope, the latter is withdrawn and the small cannula replaced by an 11.0-mm one using the trocar dilatation system.

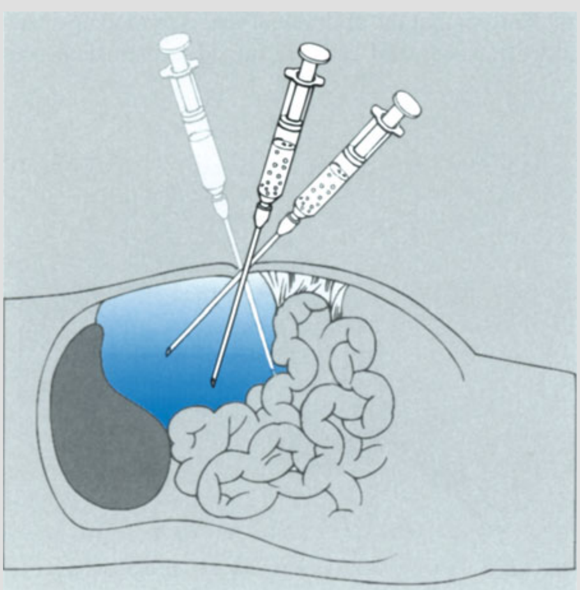
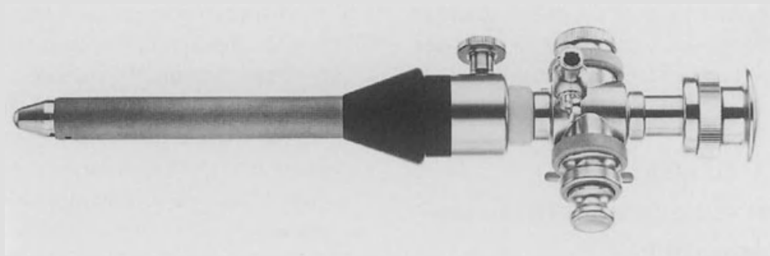


Fig. 13.6. Sounding test for assessment of the CO_2 cushion beneath the intended site of trocar insertion

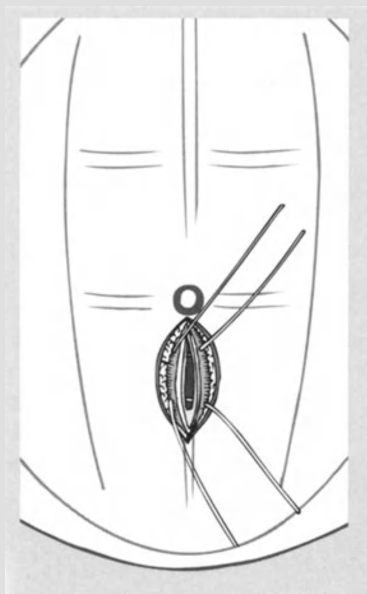
In difficult cases with irregular or pitted scars, it is preferable to insert a 5.5-mm trocar and cannula, perhaps at a site earmarked for one of the accessory sites for instrument insertion, well away from the scarred region. A 5.0-mm telescope is then introduced to scan the peritoneal cavity. The large telescopic trocar and cannula can then be inserted under vision.

Open Laparoscopy

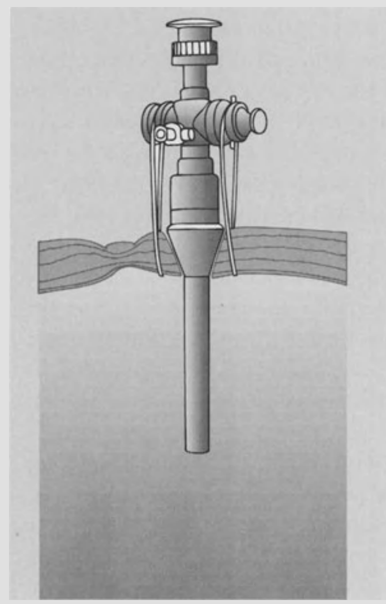
The main advantage of open laparoscopy is the avoidance of vascular injuries which, though rare, are nevertheless encountered and may indeed be life threatening. The technique of open laparoscopy consists of surgical exposure of the peritoneal cavity through an incision just beneath the umbilicus. Although an ordinary cannula may be used, the procedure is best performed using the cannula first described by Hasson in 1974 and which has since been modified. The modern version of the Hasson's cannula (Fig. 13.7) has an outer sliding olive which can be fixed to the cannula shaft by a screw arrangement. This allows the surgeon to adjust the length of the cannula inserted into the peritoneal cavity. The bulbus end of the olive maintains the seal at the site of entry through the linea alba. The struts on the either side of the olive are used for the anchoring



13.7



13.8a



b

Fig. 13.7. Modern version of Hasson's cannula (Storz)

Fig. 13.8. a A vertical 2.0-cm skin incision is made in the immediate subumbilical region. The linea alba is identified and divided in the same line between two artery forceps. The extraperitoneal fat and underlying peritoneum are incised to open the peritoneal cavity. Two 1/0 sutures are inserted at either end of the wound, each catching the two edges of the linea alba. **b** Hasson's cannula in place

sutures. The third component of the assembly is the blunt obturator which fits inside the cannula.

A vertical 2.0-cm skin incision is made in the immediate subumbilical region. The linea alba is identified and divided in the same line between two artery forceps. The extraperitoneal fat and underlying peritoneum are incised to open the peritoneal cavity. Two 1/0 sutures are inserted at either end of the wound, each catching the two edges of the linea alba (Fig. 13.8). The modified Hasson's cannula with obturator is then introduced into the peritoneal cavity. The obturator is removed and the appropriate position of the olive on the cannula shaft is adjusted to maintain the desired insertion of the cannula tip (about 1.0 cm from the parietal peritoneum). The olive is fixed in this position by the screw mechanism. The two end sutures are then tied to the struts on the olive and the gas line connected to the side port of the cannula. On completion, the two sutures are released from the struts and, following removal of the cannula and desufflation, are tied to close the fascial defect. Open laparoscopy can also be performed using a standard 11.0-mm cannula. In this instance, a purse-string suture is needed to ensure a tight seal around the cannula.

Open laparoscopy is used routinely by some surgeons. There is no doubt that the practice is safe and it does not prolong the procedure overall. The problem with it relates to the siting of the Hasson's cannula in patients who have had previous surgery as the subumbilical position may not be the desired site in these patients. In these cases an attempt should be made to locate the cases of these adhesions prior to choosing the site of insertion of the Hasson's cannula.

Management of Collapse During Induction of Pneumoperitoneum or Initial Trocar Insertion

The causes of hypotension during this stage of a laparoscopic procedure are shown in Table 13.1. By far and away the most common and important is bleeding, and this accounts for the vast majority of deaths associated with both diagnostic and therapeutic laparoscopy. In most instances, the bleeding is retroperitoneal, but, when unrecognized and progressive, it may burst through into the peritoneal cavity with sudden massive bleeding and a fatal outcome.

Much less commonly, hypotension is associated with significant arrythmias due to hypoxia from inadequate ventilation, particularly in the Trendelenberg position or myocardial infarction or pneumothorax (least common). Bradycardia is frequent, especially in the elderly. It results from reflex vagal stimulation due to stretching of the peritoneal membrane or local irritation with CO_2. It is largely prevented by slow induction of pneumoperitoneum and premedication with atropine.

Gas embolism with CO_2 is very rare. In animal experiments, volumes in excess of 1.0 litre injected intravenously are needed before the cardiac output falls significantly. In the few cases of gas embolism reported in the literature, evidence of direct vascular injury has not always been present. Cases are, however, documented when CO_2 embolism resulted from the Veress needle penetrating the uterus or the liver. The practical approach to sudden collapse of the patient is as follows:

Table 13.1. Causes of hypotension during induction of pneumoperitoneum and initial trocar and cannula insertion

Cause	Comment
Bleeding	Retroperitoneal, most common cause of death
Inadequate ventilation	Ventricular arrythmias
Heart failure	Myocardial infarction
CO_2 embolism	Rare, Veress needle in uterus or liver
Pneumothorax	Rare

1. If the hypotension and tachycardia are not associated with significant cardiac arrythmias, bleeding must be assumed to be the cause. If the hypotension is severe, all instruments are left in situ, and an immediate midline laparotomy is performed. It is important that the Veress needle or trocar and cannula assembly is not removed before the abdomen is opened.
2. If the hypotension is mild to moderate, a quick scan of the peritoneal cavity with a forward-viewing telescope is performed. If a haematoma is documented, this is inspected over a period of several minutes. If seen to be expanding, an immediate laparotomy is undertaken.
3. If the hypotension is associated with cardiac arrythmias, e.g. bigeminal rhythm, ventricular ectopic beats, ventricular tachycardia or fibrillation, immediate cessation of the insufflation and correction of hypoxia together with the necessary resuscitation measures are warranted. Under these circumstances, it is best to postpone the operation.
4. Gas embolism is best diagnosed by a precordial Doppler probe which will reveal a mill-wheel murmur in which case the patient should be immediately placed in the left lateral position with the head down to minimize the right outflow tract obstruction.

Factors Facilitating Laparoscopic Surgery

Strict attention to detail and careful preparation and planning will be rewarded by a smoother, quicker operation, avoiding frustration and minimizing the risk of complications.

Patient Position

The supine position is used for the creation of a pneumoperitoneum and manipulation of the small and large bowel. When a view of the supracolic compartment is required, head-up tilt of the table allows the omentum, colon and small intestine to move inferiorly by gravity. Conversely, a good view of the pelvic contents is obtained by the Trendelenberg tilt. If visualization of the colon in the paracolic gutters is needed, a lateral tilt (either left or right) is helpful. Care must be taken to stabilize the patient on the table during any tilting away from the horizontal. This is important to prevent pressure being exerted on unprotected limbs or bony points if a small amount of slipping occurs.

Stabilization can be achieved by supports under the arms, stirrups or, better still, a safety belt that anchors the pelvis to the table. The head and arms are usually well supported by anaesthetic arm boards.

Maintenance of an Adequate Pneumoperitoneum Throughout the Procedure

An adequate pneumoperitoneum is crucial to safe laparoscopic surgery since on it depends adequate visualization of the relevant anatomy. Particular attention to maintenance and assembly of the instrumentation to avoid valve malfunction and intact washers is crucial if non-disposable cannulae are used. Gas leaks around the shaft of the cannula are prone to occur when the incident angle of the cannula (usually the telescopic one) is such as to depress the abdominal wall around the entry site. When this position is necessary, it indicates that the siting of this cannula has been incorrect, and the insertion of an another in the appropriate place is indicated.

Another important consideration relates to adequacy of gas inflow. If the gas line is attached to the telescopic cannula (usual arrangement), an 11.0-mm rather than a 10.5-mm non-disposable cannula should be used as the space between the telescope and the inner wall of the shaft of the cannula is wider, thereby allowing a higher gas inflow from the insufflator.

Nasogastric Aspiration and Catheterization of the Bladder

Complete decompression of the stomach by Fr 14 nasogastric tube (Salem sump suction type) serves three purposes. During insufflation accidental penetration of the stomach is made less likely. Secondly, visualization of the contents of the supracolic compartment sac is enhanced. During reversal of anaesthesia, particularly during the danger period shortly after extubation, the risk of vomiting due to a stomach bloated with gas is minimized.

Apart from being a safe precaution during initial insufflation, decompression of the urinary bladder is essential for good access to the pelvic organs.

Laparoscopes, Warmers and Holders

Although it requires familiarization, the 30° forward-oblique telescope is preferable to the forward-viewing optic for tissue dissection and approximation. In the first instance, with the cable pointing upwards, it allows the surgeon to look down on the operative field rather than tangentially. Furthermore, it permits rapid changes of viewing angle by simple rotation of the telescope. However, a system to hold the telescope and endocamera to prevent rotation and change of view is necessary if the forward-oblique telescope is used. In difficult cases, it is advantageous to mount the camera on a beam splitter to allow direct viewing down the laparoscope simultaneously with television monitoring of the operative field.

Prior warming of the laparoscope is essential to establish and maintain a good view since this prevents condensation of the warm saturated air inside the peritoneal cavity on a cold lens surface. There are commercially available dry telescope warmers. However, the author prefers immersion of the optics in a warm sterile container filled with water kept at a constant temperature of 50°C inside a water bath. During operations, blood and tissue may cloud the lens and the same warming system is used to immerse and clean the optic while at the same time re-warming it.

The use of a telescope camera holder which is easily adjustable has several advantages. By dispensing with the cameraman, it creates more elbow room around the immediate environment of the operating table and facilitates two-handed manipulations which are essential for tissue approximation. The ideal holder should permit rapid and smooth adjustment in all directions: sideways, to monitor and guide instrument insertion towards the operative field; in and out, to change from wide-angle to close-up viewing; and up/down, to alter the incident angle with the horizontal. The various laparoscope holders are reviewed in Chap. 2.

Measures to Ensure Safe Application of Electrocautery

General Consideration

Irrespective of the nature, high-frequency electrocautery can only be used in the presence of CO_2. Although N_2O is not inflammable, it supports combustion and therefore cannot be used in laparoscopic work if the use of electrocautery is contemplated.

Monopolar Electrocautery

There are certain basic considerations which must be met to ensure safe use of monopolar electrocautery during laparoscopic surgery. The maximal power output has to be matched with the application, and in this respect high-output units are dangerous because the adjustment of their output in the low power range is imprecise and unreliable (see Chap. 7).

The neutral electrode should have an even surface and is applied to the patient's upper thigh covering a large area of clean hairless skin. Special efforts are made to ensure that the patient's skin does not come into contact with metal components of the operating tables, chucks and restraining devices or damp clothing. The connecting cables to the neutral and active electrodes must be in perfect condition with respect to their insulation and connector plugs. The monopolar high-frequency unit must not be operated in the vicinity of an ECG electrode (minimal distance of 15 cm). The minimal power setting should be employed with any current, and this should not be activated until the tissue is grasped and lifted to ensure that adjacent organs are not in contact with the active electrode. The non-insulated part of the active electrode must not touch any metal, telescope or cannula. Electrocoagulation should be applied to the thinnest point of the structure or adhesion to prevent secondary coagulation from the high current density. If the required coagulation or cutting effect is not achieved, a quick check of the following is made: neutral electrode is in position, all connections are correct, metallic parts of the instruments and electrodes are clean, there is no shorting due to inadvertent contact between active electrode and metal (optics and cannula). This check should be performed before increasing the power output of the generator.

Bipolar Electrocautery

The output for bipolar endoscopic application should be in the range of 40–80 W. If a combined machine is used, it must have a separate bipolar circuit. Bipolar generators do not require a neutral patient electrode, but the combined machines do, and the same safeguards described above with regard to safe application of the neutral electrode must be strictly adhered to. When using bipolar electrocoagulation, only the minimal power necessary is used, and every precaution must be taken to avoid contact between the active electrode and metal instruments. The tips of the electrode must be kept clean as encrusted coagulated tissue on the tips of the instrument impairs the coagulation efficiency.

Conversion to Open Surgery

The safety of laparoscopic surgery is dependent on the rapid conversion to an open procedure whenever the need arises. This is the reason why laparoscopic surgery should only be performed by fully trained abdominal surgeons. The underlying principle is that no surgeons should attempt a laparoscopic operation unless they are fully competent or privileged in performing the equivalent operation by the conventional open technique. Equally important, the patient should consent to this eventuality. The sensible surgeon will not interpret the need to convert to open surgery as a failure of therapy but simply as the course of action needed to ensure a satisfactory outcome in the individual patient.

Final Check and Inspection of Stab Wounds

After each laparoscopic procedure, a thorough inspection is advisable, not just of the operative area but of the entire peritoneal cavity to ensure against missed trauma during the induction of the pneumoperitoneum or initial trocar insertion, to establish that the peritoneal gutters and pelvis are dry and to inspect the stab wounds for bleeding or haematoma formation.

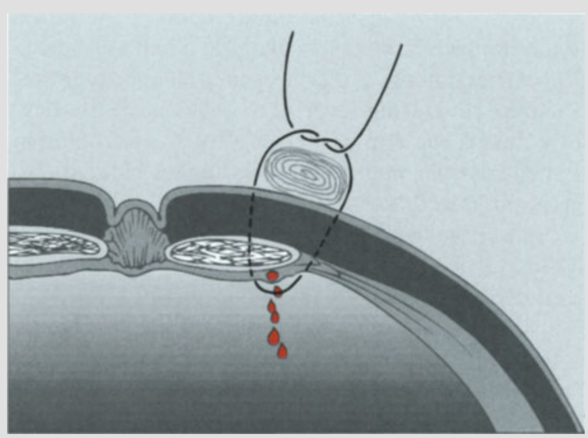


Fig. 13.9. Technique for control of abdominal wall bleeding using the large 60 mm needle (Fig. 13.10). The ends of the suture are tied over a gauze roll

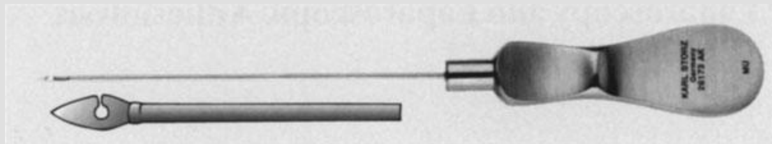


Fig. 13.10. Straight suture holder (Storz)

Bleeding from the stab wounds is most commonly from epiperitoneal vessels close to the posterior rectus sheath. This situation is readily dealt with by a 2/0 non-absorbable suture on a 60-mm (hand) straight cutting needle. This is introduced through the abdominal wall to one side of the bleeding point. The needle is grasped internally by a 5-mm needle holder and the suture partly drawn in before the needle is reversed and passed through the abdominal wall on the other side of the bleeding point. The two ends of the suture are then pulled tight and tied over a gauze roll (Fig. 13.9). The suture is cut and removed 12 h later. If available, the same procedure can be more quickly performed by the use of the straight suture holder (Fig. 13.10) which is similar in principle to the cobbler's awl. With the suture threaded in, the holder is passed through the abdominal wall on one side of the bleeding point. The suture is then grasped internally before the suture holder is withdrawn. It is then re-inserted (unloaded) on the opposite side of the bleeding point. The suture is threaded through the eye of the straight holder which is then exteriorized.

Infiltration of the wounds with long-acting local anaesthetic (e.g. bupivacaine) reduces postoperative soreness. Suturing of the linea alba and rectus sheath is advisable for the large stab wounds (11 mm) to avoid hernia formation. All the skin wounds are closed with subcuticular absorbable sutures or skin tapes.

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14 Diagnostic Laparoscopy and Laparoscopic Adhesiolysis

A. Cuschieri

Introduction

There is no doubt concerning the diagnostic value of laparoscopy in general surgery, gastroenterology and oncology. The maximal benefit is derived if surgeons use this diagnostic facility regularly as an integral part of their routine practice. Often the benefit extends beyond establishing the diagnosis in that this simple and safe diagnostic procedure influences the subsequent management of the patient. In some instances, it avoids the need for a laparotomy and reduces the cost of treatment for this reason and by obviating the need for expensive imaging tests. In the latter respect, it is of special practical benefit in underprivileged countries where high technological imaging facilities are not available. This chapter addresses three aspects of laparoscopy in surgical practice:

1. Its diagnostic potential in the elective and emergency situation.
2. The ancillary methods which enhance or confirm the diagnostic potency of the procedure.
3. Laparoscopic adhesiolysis.

Diagnostic Laparoscopy

Equipment

Standard. This is identical to that described in previous chapters although the telescope used is smaller (6.5 mm) and is introduced through a bevelled 7-mm cannula, preferably with a conically tipped trocar as this minimizes haematoma formation through muscular or vascular injury. The usual site of insertion of the laparoscopic trocar and cannula is below or to the side of the umbilicus. This position is changed in the presence of abdominal scars with the same precautions used as outlined in Chaps. 7 and 13. Viewing may be direct monocular or through the television monitor using an attached charge-coupled device (CCD) camera. The telescope may be forward viewing or 30° forward oblique. The latter is preferable, especially for close-up viewing of the surface architecture of organs such as the liver and for obtaining target biopsies under vision. In addition, by rotation of the telescope, it allows different angles of inspection of any lesion encountered. An accessory 5.5-mm trocar and cannula assembly is placed under vision most commonly in the left hypochondrium. This is necessary for the palpating probe. Other cannulae may need to be inserted in the individual case depending on requirements.

Minilaparoscopy. The minilaparoscopy set (Fig. 14.1) was designed for emergency examination under sedation and local anaesthesia. The sterile basic set is kept on a mobile cart which also houses the insufflator, light source and suction/irrigation equipment (Fig. 14.2) so that the procedure can be performed in the emergency room or by the patient's bedside.

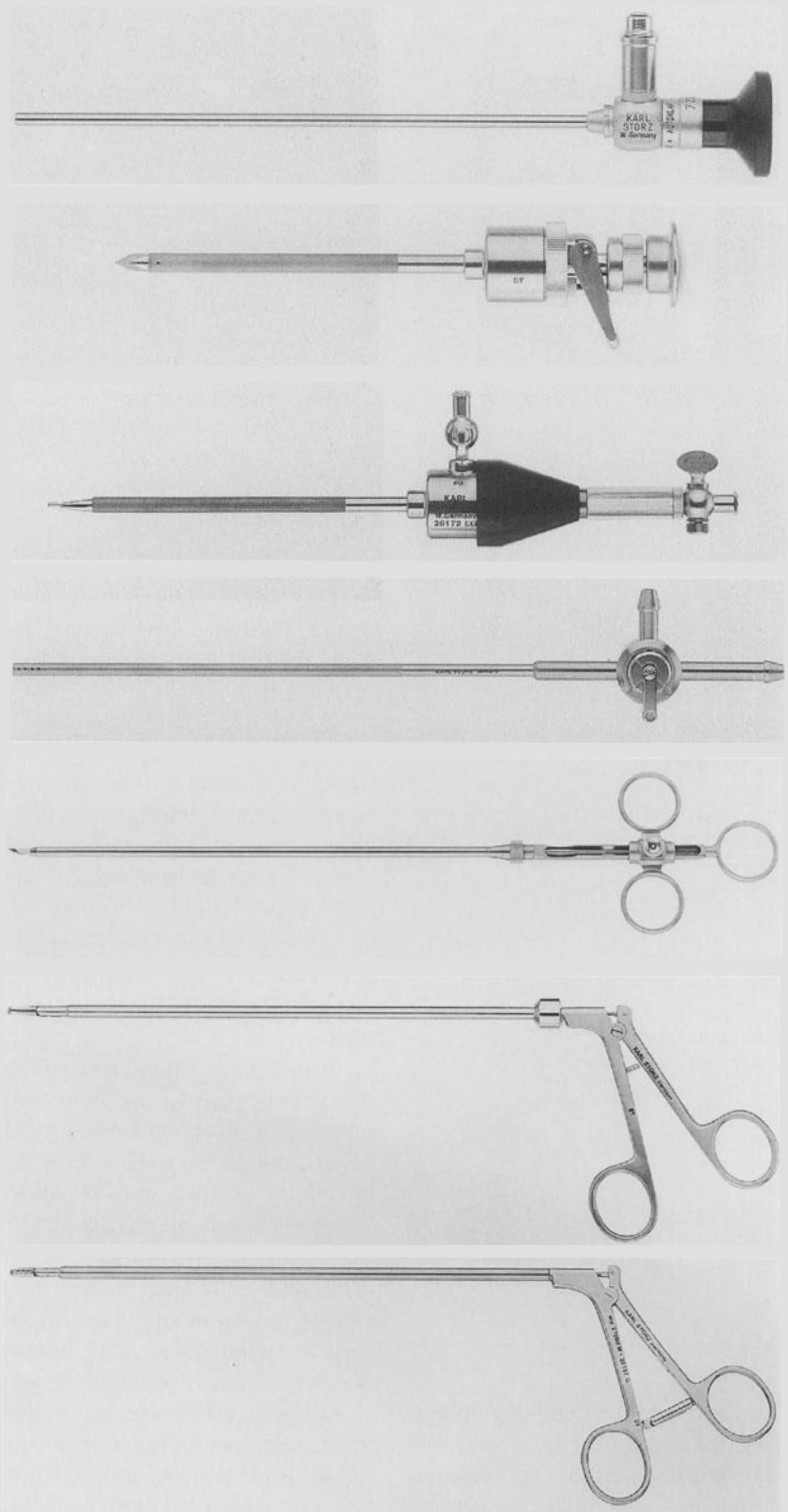
Indications

The clinical situations where laparoscopy can provide useful information which either establishes the diagnosis or influences subsequent management of the patient are outlined in Table 14.1.

Liver Disease

Laparoscopy is used extensively in hepatology. Often the macroscopic appearances alone are highly diagnostic although biopsy confirmation is always desirable. The non-malignant disorders which are of special importance to the surgeon and which can be documented by laparoscopy are: hepatic fibrosis, cirrhosis, fatty degeneration, portal hypertension, cholestasis and benign local lesions such as cysts, haemangiomas, microhamartomas, focal nodular hyperplasia and adenomas.

There is no other investigation which approximates the diagnostic yield of laparoscopy for the detection of cirrhosis. The procedure clearly demonstrates the abnormal surface appearance of the disease: the scar-



a b c d e f g

Fig. 14.1 a–g. Minilaparoscopy instrument set, consisting of: (**a**) telescope (4 mm); (**b**) accessory cannula; (**c**) Veress needle inside telescope cannula; (**d**) irrigation suction cannula; (**e**) laparoscopic protected pointed knife; (**f**) atraumatic grasper; (**g**) traumatic grasper

Fig. 14.2. Minilaparoscopy equipment housed in a purpose-built mobile trolley for use in abdominal trauma

Table 14.1. Indications for laparoscopy

Elective
Assessment and biopsy of acute and chronic liver disease
Primary and secondary liver tumours
Staging of malignancy
Ascites of unknown origin
Undiagnosed abdominal mass
Fever of unknown origin
Chronic abdominal pain
Pelvic adnexial disease in the female
Impalpable testis
Emergency
Acute abdomen
Abdominal trauma

ring, regenerative nodules and the enlarged gallbladder. In addition, the overall size of the liver is readily appreciated. The size of the regenerating nodules is so variable in the individual case as to render the distinction between macro- and micronodular cirrhosis inappropriate in the majority of patients. Aetiological implications of the cirrhosis on the basis of nodule size are therefore unsound. Very large nodules (>1.0 cm) with dense fibrosis are, however, indicative of post-

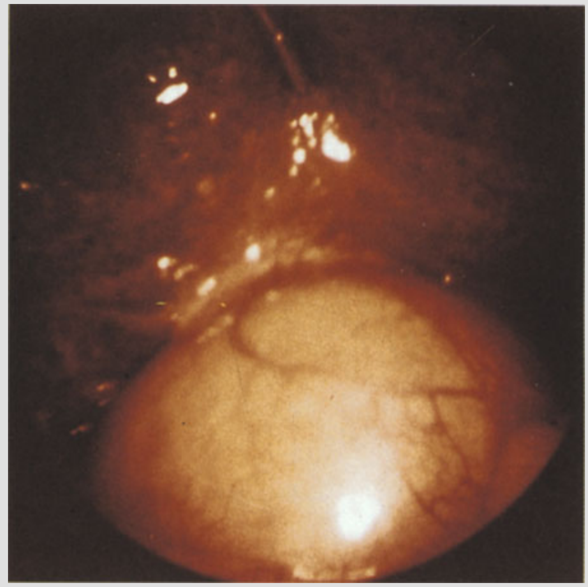


Fig. 14.3. Enlarged distended gallbladder in a patient with cancer of the head of the pancreas

necrotic scarring irrespective of aetiology. The macroscopic assessment of the cirrhotic liver should always be accompanied by a laparoscopic liver biopsy. In addition to its greater diagnostic yield, laparoscopic liver biopsy for cirrhosis is safer than the blind percutaneous procedure because haemostasis can be ensured by compression or electrocoagulation of the biopsy site. This is of real practical benefit in patients with compromised liver function and disordered coagulation.

Intrahepatic cholestasis due to primary or drug-induced liver disease can be distinguished from large bile duct obstruction caused by lesions of the extrahepatic biliary tract, the nature of which can be determined by laparoscopically guided cholangiography and targeted biopsy/cytological studies during the same session. The dramatic appearance of the large distended gallbladder caused by malignant obstruction of the lower bile duct can be readily identified (Fig. 14.3) and, if necessary, temporary transcystic decompression instituted laparoscopically.

Benign local lesions can be identified, monitored when necessary and in some instances treated laparoscopically. Haemangiomas are not infrequent lesions, and, although the majority can be identified by imaging tests such as ultrasonography and computed tomography (CT), the true nature of some is missed by these imaging tests. This may lead to percutaneous ultrasound-guided biopsy with disastrous consequences. The vascular nature of these lesions should be con-

Fig. 14.4. Secondary deposits in the liver from a primary rectal cancer

firmed or excluded by laparoscopy in the first instance. Benign hepatic adenomas can be identified and monitored by serial laparoscopy to document regression or progression. Adenomas appear as greyish-white smooth swellings with a fine network of surface vessels. The liver parenchyma around the base of the lesion extends as a thin layer for a few millimetres over the margins of the lesion. In some instances, as with hepatic non-parasitic simple cysts, definitive treatment by aspiration followed by deroofing can be effected laparoscopically.

Laparoscopy is invaluable in the detection and management of malignant liver tumours. Primary hepatomas arising in a normal liver form smooth intraparenchymal lesions which cause surface elevation of the liver parenchyma. Their exact lobar/segmental location, size and extrahepatic involvement can be determined laparoscopically. The laparoscopic information can influence the management of the patient by indicating the feasibility of hepatic resection or the need for transplantation. Hepatomas arising on a background of cirrhosis (cirrhomimetic) form whitish elevated or nodular areas of tissue which contrast with the darker appearance of the regenerating nodules. They are often multicentric. Much less commonly, the neoplastic foci exhibit a green discolouration.

To the general surgeon, the detection and biopsy confirmation of secondary deposits (Fig. 14.4) in the liver from common cancers constitutes one of the most important benefits of laparoscopy. It avoids the need for other expensive investigations and, in some patients, an operative intervention. Not infrequently, the "solitary metastasis" diagnosed by CT is observed to be multiple at laparoscopy, with one large deposit surrounded by several surface satellite lesions over a variable distance. In terms of their laparoscopic appearances, secondary deposits in the liver assume the following appearances: discretely nodular (potentially resectable), expansively nodular (occasionally resectable), nodular and infiltrating, miliary and diffusely infiltrating. The last three are always inoperable and usually associated with a very limited survival.

Staging of Malignancy

Apart from the detection of hepatic secondary deposits, laparoscopy gives reliable information on the degree of advancement of common intra-abdominal cancers and lymphomas. In the author's experience, laparoscopy is particularly useful as an immediate prelaparotomy procedure in the following cancers: pancreatic, lower oesophageal, gastric and colorectal. In these tumours, it is the only reliable method for the detection of peritoneal deposits. Laparoscopy is 100% accurate in detecting non-resectability but overestimates the operability rate. In patients suffering from these tumours, the inoperable stage can therefore be identified and laparotomy avoided if palliation can be performed laparoscopically or by non-surgical means. The question which has to be addressed by prospective clinical studies is whether laparoscopy should be used routinely or selectively in these patients. With the exception of pancreatic cancer, the author's practice has changed to the latter since routine laparoscopy before laparotomy for all patients imposes an inordinate case load. In our view, laparoscopy is indicated in patients with oesophageal, gastric and colorectal cancer when the preoperative work-up and clinical findings suggest the possibility of advanced metastatic disease and the patient's symptoms can be palliated by endoscopic or other non-surgical means.

There is good evidence that laparoscopy can rapidly confirm clinical stages III and IV of Hodgkin's disease and allow histological confirmation and typing. In patients with suspected clinical stages I and II, laparoscopic inspection of the liver with multiple liver biospies and single splenic biopsy can obviate the need for staging laparotomy in up to 70% of patients. Similar considerations apply to patients with non-Hodgkin's lymphomas.

Ascites of Unknown Origin

In the majority of patients with ascites, the aetiology can be ascertained by clinical and laboratory studies including culture and cytological examination of a sample of ascitic fluid. In some 20% of cases, however, the diagnosis remains obscure despite the standard work-up. Laparoscopy is generally reserved for these patients. It is particularly useful for establishing the diagnosis of ascites associated with intra-abdominal inflammatory disease such as tuberculous peritonitis and Crohn's disease, ascites associated with liver disease and that accompanying occult intra-abdominal malignancy. The macroscopic appearances of the fluid in malignant ascites is extremely variable. It may be clear and yellow, dark green in malignant bile duct obstruction, chylous as a result of malignant occlusion of the main lymphatic pathways, frankly blood stained and gelatinous or mucoid.

Chronic Abdominal Pain

The most common indication for diagnostic laparoscopy in the author's practice is chronic abdominal pain. Often these patients are referred from other physicians including internists after extensive investigations have failed to establish the cause of the recurrent abdominal pain. We have undertaken both retrospective and prospective studies on the value of laparoscopy in the management of these patients. These have consistently shown positive findings which influenced subsequent management in 30 % and normal laparoscopic appearances in the majority. The former group undoubtedly benefit from subsequent treatment based on the laparoscopic findings. The outcome of patients with negative laparoscopic findings is far less favourable, as despite reassurance, the vast majority have continued to experience abdominal pain and some have indeed gone on to exploratory laparotomy with a negative result.

Other Conditions

There remains a miscellaneous group of patients in whom laparoscopy may be needed either to establish a diagnosis or to provide further information needed to plan the right surgical treatment. Examples of the former include patients with undiagnosed or obscure intra-abdominal masses and patients with pyrexia of unknown origin, especially in tropical countries. A good example of pretreatment laparoscopy is the impalpable testis, where the intra-abdominal location of the testis, its size and feasibility of orchiopexy can be determined before surgical exploration.

Emergency

Acute Abdomen

Emergency laparoscopy is exceedingly useful in the management of patients with acute right iliac fossa pain and tenderness. This particularly applies to females in whom the differentiation between acute appendicitis and acute ovarian pathology, ectopic pregnancy and salpingitis can be readily made. In patients with salpingitis, culture material can be obtained and definitive treatment, i. e. evacuation of pus and saline lavage can be instituted laparoscopically. Ovarian pathology and ectopic pregnancy can also be treated via the laparoscopic approach. In patients of both sexes, the exclusion of acute appendicitis avoids unnecessary surgery with substantial cost saving to the hospital. If appendicitis is confirmed, appendicectomy can be performed laparoscopically (see Chap. 15).

The diagnosis of mesenteric vascular insufficiency can be difficult, and there is no reliable diagnostic test. Often these patients are old and have co-existent cardiovascular and chronic obstructive airways disease. Laparoscopy is very useful for the detection of ischaemic bowel and for establishing the need for operative intervention in these poor-risk patients.

Another useful indication for emergency laparoscopy is in the diagnosis of acute peptic perforation. This is particularly relevant nowadays as suture closure and peritoneal toilet can be effected laparoscopically (see Chap. 22).

Abdominal Trauma

The value of minilaparoscopy in the diagnosis and management of acute abdominal trauma has been validated by both prospective and retrospective studies. Its main advantage over abdominal lavage is in obviating laparotomy in those patients with minor injuries which can be managed conservatively and in those patients in whom intra-abdominal bleeding has stopped spontaneously. It is indicated in stab wounds and blunt injuries, but is contraindicated in high-velocity missile injuries.

In patients with stab wounds, minilaparoscopy readily identifies complete penetration of the abdominal wall. In the absence of the latter, these patients can be discharged with complete safety after toilet and suture of their abdominal wall wounds.

Although there is a strong argument for routine use in all stable patients with blunt abdominal trauma, minilaparoscopy is particularly indicated in the following clinical situations:

1. When the clinical picture and physical signs are obscured by impaired level of consciousness from any cause
2. Equivocal signs on physical examination in a conscious patient
3. Unexplained tachycardia and hypotension in a previously stable patient

Contraindications

The absolute contraindications are uncorrected bleeding disorders, the cardiovascularly unstable patient (heart failure), unstable abdominal injuries and abdominal trauma inflicted by gun shots or high-velocity missiles, chronic respiratory failure and abdominal wall sepsis. Caution is needed in the presence of large hiatus herniae and irreducible external hernia, but provided a low-tension pneumoperitoneum is used and desufflation is complete at the end of the procedure, laparoscopic procedures can be conducted with safety in these patients. Obesity is a contraindication if it is extreme to the extent that the instruments cannot reach beyond the layers of the abdominal wall.

Laparoscopy in the High-Risk Groups

Special precautions are needed in the following groups of patients.

Patients with Abdominal Scars. The risk here relates to the possibility of visceral trauma, and the steps and measures outlined in Chap. 7 must be followed.

Patients with Abdominal Distension by Excessive Gas or Ascites. Ascitic patients are especially at risk of intestinal trauma as the loops of small intestine are floating on the surface of the ascitic fluid. A useful practical step in these patients consists of withdrawal of sufficient ascitic fluid once the Veress needle is in situ to reduce the distension and intra-abdominal pressure before the start of the insufflation. This facilitates the creation of an adequate pneumoperitoneum without incurring a dangerous rise in the intra-abdominal pressure and greatly reduces the risk of bowel injury during the insertion of the laparoscopic trocar and cannula.

Patients with Bleeding and Coagulation Disorders. The disorder may be congenital or secondary to acquired disease, most commonly cirrhosis. The risk of bleeding applies to the stab wounds caused by the insertion of cannulae and, of course, to biopsy and fine-needle aspiration cytology. Laparoscopy in these patients should be backed by full haematological assessment and advice such that any clotting deficiency is corrected by the appropriate pretreatment. In addition, diathermy including the suction/coagulation probe must be available, and the operator must be familiar with the technique of laparoscopic abdominal wall suturing to control bleeding from any of the stab wounds (described in Chap. 7). Minimizing the number of trocars and cannulae used in these patients is a sensible option.

Patients with Cardiorespiratory Disease. Laparoscopy can be performed in these patients either under general or local anaesthesia. A fully trained anaesthetist must be in attendance, and complete monitoring of the cardiovascular and respiratory function must be maintained throughout the procedure. In these patients, a low-tension (5–10-mm Hg) pneumoperitoneum is advisable.

Preparation and Anaesthesia

Preparation

The preparation of patients for diagnostic laparoscopy includes assessment of risks for general anaesthesia. In patients considered at significant risk, the procedure is best performed under local anaesthesia with intravenous sedation. Correction of any clotting abnormality by the appropriate measure is important. Catheterization to empty the urinary bladder immediately before the procedure avoids the risk of vesical injury, particularly with the subumbilical or suprapubic approach (favoured by some gynaecologists). The catheter may be removed after the bladder is emptied or at the end of the procedure. Nasogastric intubation is needed in all patients undergoing emergency laparoscopy and may be necessary in routine elective cases if the stomach is distended with air swallowed during intubation. Shaving is unwarranted except in very hairy individuals. A diathermy pad (neutral electrode) should always be applied as electrocoagulation may be needed during the procedure. Antibiotic prophylaxis is unnecessary for routine diagnostic laparoscopy but may be dictated by the underlying condition.

Anaesthesia

In terms of ease of performance, especially when multiple cannulae are used, diagnostic laparoscopy is best conducted under general endotracheal anaesthesia with muscle relaxation and controlled ventilation. This permits the use of CO_2 as the insufflating agent without significant changes in the plasma blood gases, pH and electrolyte levels.

In patients considered unfit for the above, local anaesthesia with intravenous sedation with benzodiazepines titred to the needs of the patient is employed. In this situation, insufflation of the peritoneal cavity should be performed with nitrous oxide for two reasons. In the first place, the insufflation is less painful; and secondly, blood gas disturbances consequent on the establishment of the pneumoperitoneum are less likely, particularly if the patients breathes 30% oxygen throughout the procedure. Although N_2O is not inflammable, it supports combustion and therefore electrocoagulation cannot be used.

Local anaesthesia can be administered in three ways:

1. Infiltration of all the layers of the abdominal wall at the intended sites of cannulae insertion
2. Lower intercostal nerve block
3. Field/rectus sheath block

Technique of Elective Diagnostic Laparoscopy

Following the creation of the pneumoperitoneum, the laparoscope cannula is introduced, usually in the subumbilical position. Thereafter, the telescope is inserted and viewing commences (direct monocular or with CCD camera and television monitor). An accessory (5.5-mm) trocar and cannula is then inserted under vision in the left upper quadrant along the linea semilunaris, halfway between the umbilicus and the costal margin. This is needed for the palpating probe and suction/coagulation cannula. Other accessory cannulae are inserted in other sites as needed.

General Inspection

The procedure entails an initial general inspection of the peritoneal cavity and its contents, followed by specific inspection of diseased organs. Exposure of the various quadrants and regions is facilitated by changing the position of the operating table (head-up down and lateral tilt). For this reason, the patient should be strapped.

The supracolic compartment is examined with the table in a head-up tilt. This helps to display the anatomy and ensures that the omentum drops down by gravity away from the area of inspection. The first landmark is the falciform ligament. The liver is inspected next. With the use of the palpating probe, only the posterior surface (pars affixa) of the liver is not visible at laparoscopy. It is useful to keep the telescope some 5.0 cm from the liver to obtain a good overview. Closer inspection of the parenchyma and any focal lesions can be obtained by advancing the tip of the telescope or using the zoom facility of the endocamera. The other contents of the right hypochondrium are inspected: gallbladder, antroduodenal segment of the stomach and hepatic flexure. These organs are exposed by lifting the liver with the palpating probe. The anterior surface of the body of the stomach and the gastrocolic omentum are visualized next. The proximal stomach and the cardio-oesophageal junction are inspected after the left lobe of the liver is lifted with the palpating probe. In the left upper quadrant, the splenic colon and upper descending colon can be inspected, but the normal spleen is not accessible for inspection. This organ can only be seen when enlarged with the patient in a head-up tilt and with the table rotated well to the right. If a 30° forward-oblique telescope is used, it is turned 180° to inspect the diaphragmatic and parietal peritoneum of the upper abdomen. This completes the inspection of the supracolic compartment.

The infracolic compartment is best examined with the patient in the supine position and lateral tilt (right or left) opposite to the side being examined. The omentum; appendix; caecum; ascending, transverse, descending colon; and paracolic gutters can be inspected using the two grasping forceps technique (see below). The technique for inspection of the loops of the small intestine is described below. The lower aorta and iliac vessels can also be visualized. Both ureters can be identified in thin individuals.

A steep Trendelenburg position is required for inspection of the pelvic organs. Small bowel loops have to be lifted and placed in the abdomen before full inspection of the rectum, bladder and female pelvic organs can be made. In the female, uterine manipulation through the vagina greatly assists in viewing all parts of the pelvis. This can be achieved by a Hegar dilator within the uterine cavity with a vulsellum forceps on the anterior lip of the cervix (Fig. 14.5). For this reason, examination of the female pelvis is best conducted with the patient in the lithotomy position.

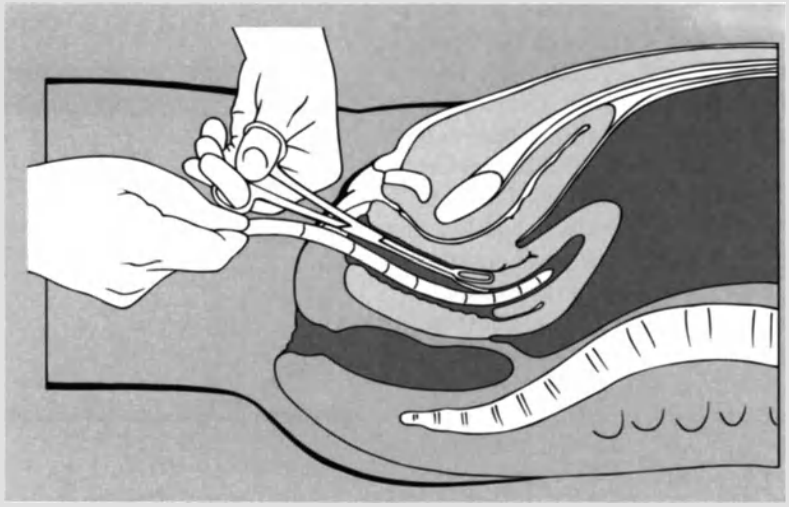


Fig. 14.5. Uterine manipulation with Hegar's dilator and vulsellum forceps assists the laparoscopic exposure of the female pelvic organs

Specific Organ Inspection

Special techniques are required for inspection of the pancreas and intestinal loops. There are two approaches for examining the pancreas: the supragastric and the infragastric. Two accessory cannulae are needed (Fig. 14.6). In addition, the following instruments are required: scissors, two insulated atraumatic grasping forceps, electrocautery cable and palpating probe. The telescope must be of the forward-oblique viewing type (30° or 45°).

The supragastric method is particularly suited to thin patients. The palpating probe introduced through the right accessory cannula (p3) is used to elevate the liver, thereby exposing the gastrohepatic omentum. A window is cut through an avascular area using scissors introduced through the left accessory cannula (p2). The palpating probe is then advanced through the aperture and used to elevate the liver substance above the lesser sac. The scissors are replaced by an atraumatic forceps which is advanced to grasp the lower margins of the hole in the lesser omentum and adjacent lesser curve. This grasping forceps is used to pull the stomach downwards and forwards. The telescope is then introduced inside the lesser sac for inspection of the pancreas.

The infragastric method gives better access to the pancreas and is favoured by the author except in thin individuals. The gastrocolic omentum near the greater

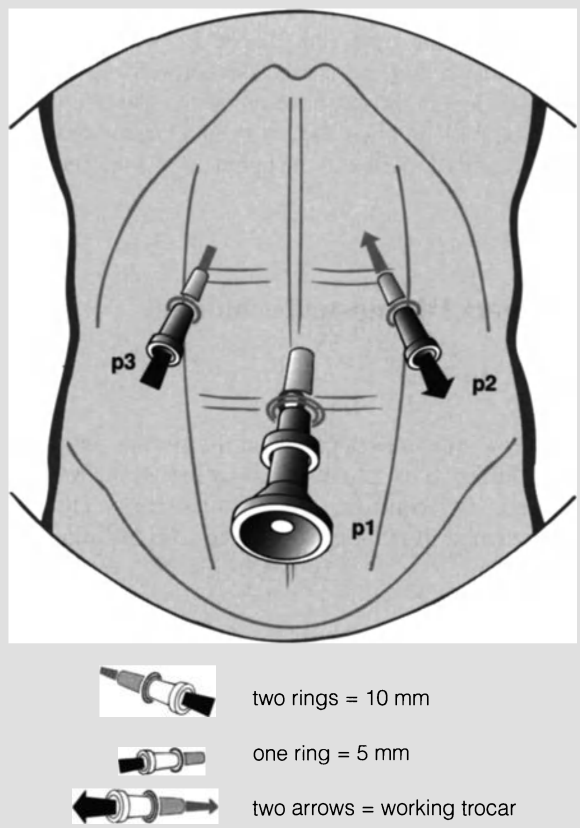
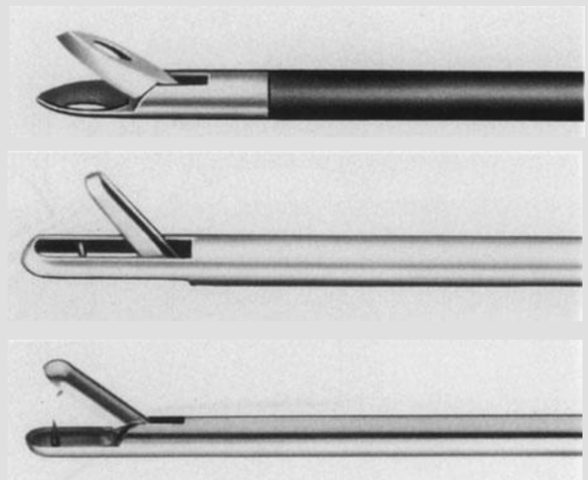


Fig. 14.6. Sites of insertion of accessory trocars and cannulae for laparoscopic inspection of the pancreas

curvature is grasped by an atraumatic forceps introduced through the right accessory cannula. An opening is cut by scissors (left cannula) in a relatively avascular area below the greater curvature. Often a few vessels require electrocoagulation during this step. The grasping forceps is then replaced by the palpating probe (right cannula), and this is introduced through the opening in the gastrocolic omentum for a distance of 5.0 cm and used to elevate the stomach. A grasping forceps introduced through the left cannula is used to stent the opening on the left side, whilst the telescope is advanced into the lesser sac for inspection of the pancreas.

The small intestine is best examined in a retrograde fashion starting at the terminal ileum. The first loop is grasped between two atraumatic forceps and inspected on either side. The first grasper (close to the caecum) is then released and applied beyond the second and so on, the process resembling "walking on stilts". Once the upper jejunum is reached, the table is tilted head down, the omentum placed in the supracolic compartment and the transverse colon lifted up. In obese patients this may necessitate the use of a third cannula. With practice, the entire small intestine from the ileocaecal junction to the ligament of Treitz can be inspected.



a

b

c

Fig. 14.7 a–c. Types of biopsy forceps. **a** Standard pointed insulated (Storz); **b** punch biopsy forceps (Storz); **c** Semm's tooth biopsy forceps (Storz)

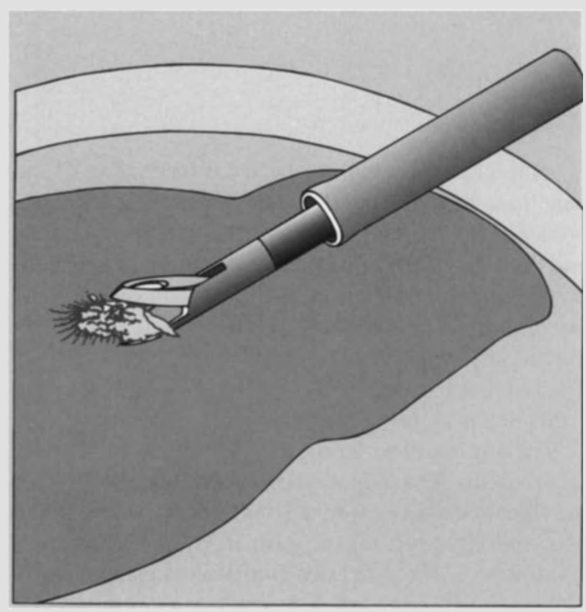


Fig. 14.8. Technique of biopsy of exophytic lesion using the pointed biopsy forceps

Ancillary Diagnostic Techniques

Biopsy

The technique used depends on the surface anatomy of the lesion. If exophytic, a biopsy forceps technique is used. By contrast, for flat lesions, including parenchymal liver biopsy, a needle core technique is employed.

Forceps Biopsy

There are three kinds of biopsy forceps: sharp point, punch and Semm's tooth and cup instrument (Fig. 14.7). The first, which is usually insulated, is the most commonly used instrument and is particularly suited for biopsy of exophytic hepatic lesions. The punch and Semm's forceps allow larger specimens to be taken from locations such as the diaphragm, parietal peritoneum and intestinal serosal surfaces.

Irrespective of instrument and intended biopsy site, the technique used is the same. A 45° angle between the line of cannula penetration (containing the biopsy forceps) and the lesion constitutes the best approach. With the instrument held in the open position, the fixed jaw is inserted beside and under the lesion, the mobile jaw is then closed over the tissue which is grasped and cut by the sharp edges of the opposed jaws (Fig. 14.8). The instrument is then withdrawn in the closed position and the biopsy retrieved. The biopsy site is then inspected for bleeding. Often, minor oozing is stopped by direct local pressure with the suc-

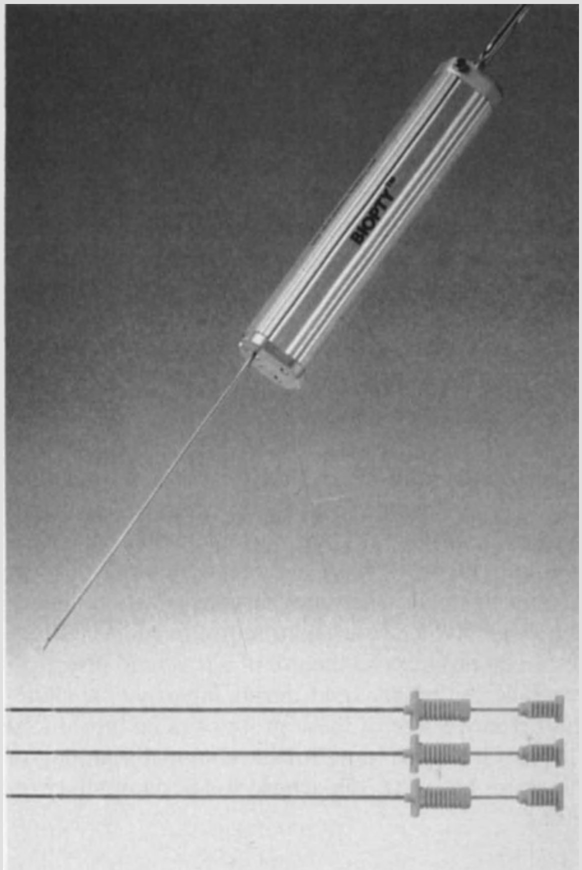


Fig. 14.9. Biopty device for precise and safe biopsy of hepatic parenchyma

tion/coagulation probe. More brisk bleeding is controlled by electrocoagulation.

Core Needle Biopsy

Core needle biopsy of the liver can be obtained by use of Menghini, Tru-Cut or Biopty device. The latter (Fig. 14.9) is a mechanized spring-loaded device which uses the Tru-Cut principle. The firing mechanism triggered by the thumb ensures rapid closure of the cutting outer cylinder. The device permits excellent single-handed control with minimal trauma to the hepatic parenchyma. Again, the liver biopsy site is inspected and any bleeding controlled as described above.

Cytology

Cytological material can be obtained during laparoscopy in three ways: brush technique, peritoneal washing and fine needle aspiration (FNA).

Brush Cytology

Brush cytology may be used alone and in combination with other biopsy techniques. It is particularly suitable for surface lesions in sites which are relatively inaccessible to the core needle biopsy or when the latter method cannot be used, e. g. flat surface lesions on the intestines. The cytology brush is inserted inside its outer protective sheath down the suction cannula. This allows better guidance by imparting rigidity to the assembly. Brushings of the lesion are taken after the outer plastic sheath has been retracted. Before withdrawal, the brush is retracted inside the plastic sheath.

Peritoneal Washings

There is increasingly good evidence from the Japanese literature that peritoneal washing yields very reliable prognostic information in patients with gastrointestinal cancer and is used routinely in some centres for the staging of ovarian, gastric and colonic neoplasms. The technique was first described for use in open surgery. The method is, however, readily adapted to staging laparoscopy for intra-abdominal tumours. The technique is very simple and entails the instillation of 200–300 ml saline into the pelvis via the suction cannula. The fluid is gently stirred in the pelvis and then aspirated back. After centrifugation, the pellet is examined cytologically for malignant cells.

Fine Needle Aspiration Cytology

In addition to aspiration of free peritoneal fluid and bile, FNA is ideal for the biopsy of pancreatic lesions and lymph node masses encountered during diagnostic laparoscopy. A 23-gauge Chiba or lumbar puncture needle attached to an empty 10-ml syringe is used. Cell yield and recovery are considerably enhanced if the lumen of the needle is first coated with heparin solution (1000 units per millilitre). This is achieved by aspirating 1 ml of the solution and then squirting it out completely before use. For pancreatic lesions, the needle can be made to traverse the stomach with complete safety. This is easier than trying to guide the needle through the opening in the gastrocolic omentum into the lesser sac. Suction by the syringe is maintained as the needle traverses the lesion in at least three directions over a period of 30 s. Suction is stopped before the needle and syringe are withdrawn. After disconnection of the needle from the syringe, the plunger is withdrawn up to the 10-ml mark. The syringe is then re-attached to the needle, the contents of which are squirted onto a glass slide. Squash preparations are made by laying a second slide on top of the first and sliding one against the other.

Cholangiography

Laparoscopic cholangiography can be performed either transhepatically or through the gallbladder. Either technique does not commit the surgeon to any procedure on the biliary tract.

Transhepatic Cholangiography

This is indicated in the absence of the gallbladder or when the organ is grossly contracted or is packed with a large stone load. The Chiba needle is introduced into the liver substance. Initially, we used to impale the right lobe medial to the gallbladder, but nowadays we prefer to insert the needle to a depth of 5 cm, pointing towards the suprahepatic vena cava, into the left lobe medial to the umbilical fissure to avoid the left branch of the portal vain. The needle is connected by PVC tubing and a three-way tap to two 50-ml syringes, one containing 20% sodium diatrizoate (Hypaque) and the other normal saline. Screening is commenced as small increments of contrast are injected. When the needle tip is in a vascular channel, contrast is seen to disappear quickly in a centrifugal direction. The needle is withdrawn slightly and contrast injection repeated until the ductal system is entered. This can be confirmed by aspiration. Enough contrast is then injected to outline the entire biliary tract. On completion, the site is inspected for bile leakage or bleeding. Usually a few seconds of compression with the suction cannula deals with this problem, but is come cases electrocoagulation may be needed.

Transcystic Cholangiography

A variety of long disposable sheathed intravenous cannulae may be used for this purpose. There are two options: direct puncture of the exposed surface of the gallbladder (usually the fundus) or entry into the gallbladder lumen through its bed after traversing the liver substance. Contrary to expectations, direct puncture of the fundus of the gallbladder usually seals very rapidly after withdrawal of the cannula, particularly if the gallbladder is emptied by aspiration prior to removal of the cannula. Entry of the gallbladder lumen through the edge of the right lobe is, however, preferred by the author as the tamponade effect of the liver substance completely eliminates the problem of bile leakage. Direct puncture of the fundus is reserved when the transhepatic method proves difficult. It is facilitated by grasping the gallbladder to apply countertraction as the needle tip is stabbed into the lumen, otherwise there is a tendency for the gallbladder wall to recede away from the needle.

Ultrasound Examination

Ultrasound probes are available for direct scanning of the liver, gallbladder and biliary tract and pancreas during laparoscopy. Their current limitation is size, and the majority have to be introduced through 12-mm cannulae. Their use will considerably enhance the scope of diagnostic laparoscopy. In addition, studies are in progress on the use of ultrasound probes to examine the biliary tract during laparoscopic cholecystectomy. Some of these probes can be introduced through the cystic duct for intraluminal scanning of the lower bile duct, sphincteric and periampullary regions.

Laparoscopic Adhesiolysis

Division of adhesions, usually caused by previous surgical intervention, may be necessary to obtain access both during diagnostic and operative laparoscopy. On other occasions, laparoscopic adhesiolysis may be undertaken with a therapeutic intent in patients with chronic abdominal pain and as an emergency for the relief of acute small bowel obstruction caused by compression by adhesive bands, although the laparoscopic experience with the latter situation is limited at present.

Instrumentation

The instruments needed for laparoscopic adhesiolysis include atraumatic grasping forceps, adhesion grasping forceps, bipolar grasping forceps electrocautery cable and twin-action scissors (Fig. 14.10). As a two-handed technique is needed, two operating accessory 5.5-mm trocar and cannula assemblies need to be inserted in the optimal position.

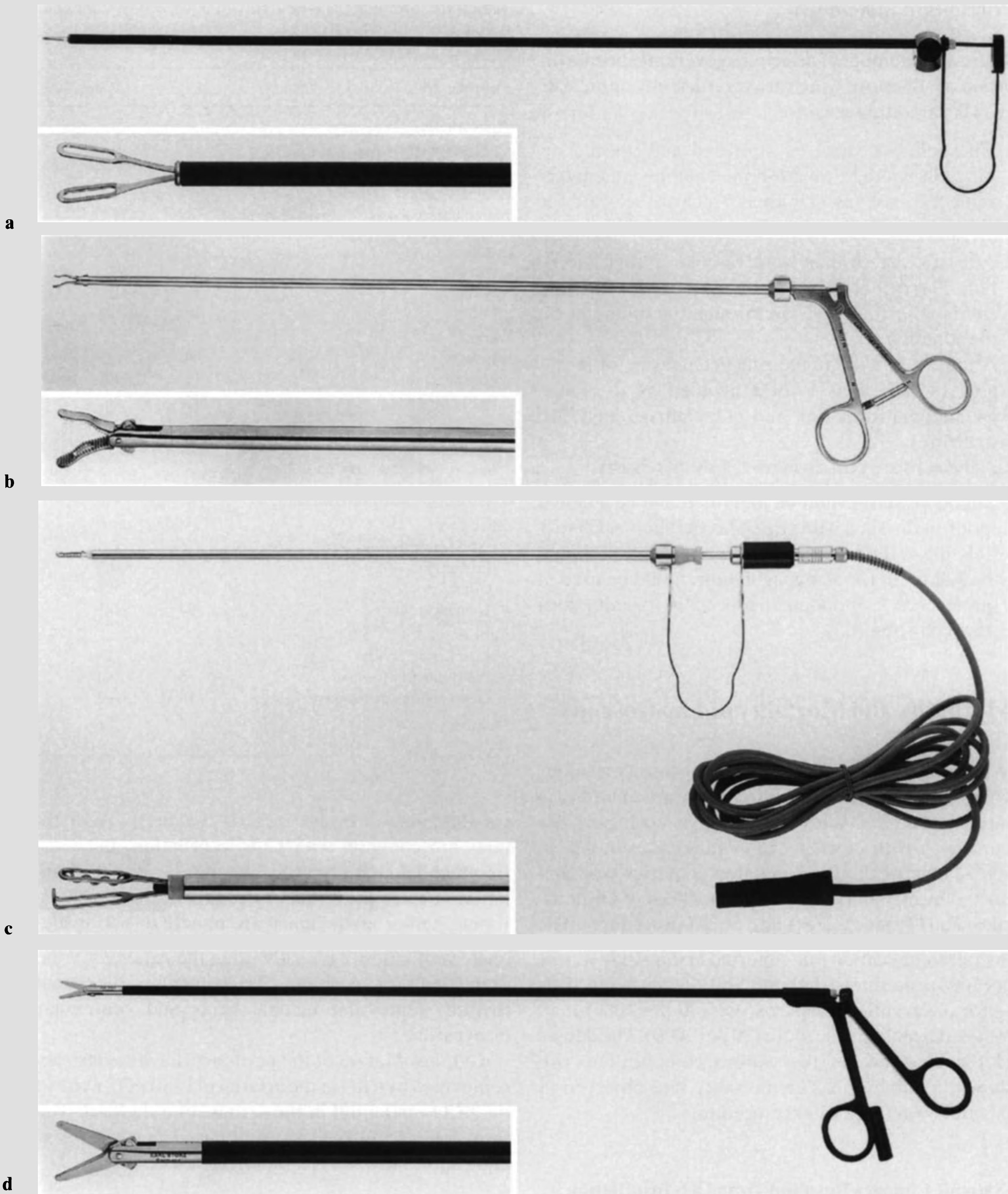


Fig. 14.10 a–d. Instruments for laparoscopic adhesiolysis: (**a**) atraumatic grasping forceps (Storz); (**b**) adhesion grasping forceps (Storz); (**c**) bipolar grasping forceps (Storz); (**d**) electrocautery cable and twin-action scissors (Storz)

Principles of Adhesiolysis

There are a number of principles governing the safe division of adhesions which are insufficiently appreciated. The important ones are:

1. The adhesion must be stretched and opened up along its width to establish the anatomy and determine the least vascular areas which are selected for division.
2. Adhesions are usually least vascular at their insertion. This is therefore the site of choice for division and is safer than division through the midpoint of the adhesion.
3. Although in widespread practice, teasing or stripping of adhesions is best avoided as it causes haematoma formation and may damage adjacent structures.
4. Adhesions are best divided cleanly by scissors.
5. Blood vessels should be identified and coagulated prior to division. The principles outlined in Chap. 7 relating to the safe use of electrocoagulation should be followed. Bipolar coagulation should be used in preference to monopolar especially for adhesions involving bowel.

Morbidity and Mortality of Laparoscopy

With adequate precautions and the necessary training, laparoscopy is a safe procedure. There are a number of large reported series of non-gynaecological laparoscopy with mortality rates ranging from 0% to 0.1%. One of the most detailed enquiries was conducted by members of the Royal College of Obstetricians and Gynaecologists into 50247 procedures. The overall complication rate reported in this study was 34 per 1000 procedures, the complication rate being higher for interventional laparoscopy (40 per 1000) than for the diagnostic procedure (30 per 1000). The details of the incidence of the various complications are shown in Table 14.2. The mortality rate observed in this audit was 0.1 per 1000 procedures.

Table 14.2. Morbidity and mortality of laparoscopy. Confidential enquiry by the Royal College of Obstetricians and Gynaecologists on 50247 procedures in 1978

Complication	*n*	Rate/1000
Anaesthetic		
Anaesthetist	38	0.8
Cardiac arrest	9	0.2
Cardiac arrhythmias	20	0.4
Failed laparoscopy	375	7.5
Burns		
Bowel	27	0.5
Skin	13	0.3
Other	10	0.2
Trauma		
Bowel	90	1.8
Urinary tract	11	0.2
Pelvic organs	172	3.4
Haemorrhage		
Abdominal wall	125	2.5
Iliac vessels and tubal mesentery	134	2.7
Pelvic side wall and ovarian	43	0.9
Infection		
Abdominal wound	26	0.5
Pelvic	25	0.5
Chest	11	0.2
Urinary tract	24	0.5
Others		
Lost foreign body	29	0.6
Pulmonary embolism	8	0.2
Deep venous thrombosis	10	0.2
Deaths	4	0.1

Systemic Changes Resulting from CO_2 Insufflation

Insufflation of the peritoneal cavity with CO_2 results in elevation of the central venous and systemic arterial pressures. The rise in the systemic blood pressure is mainly due to a sympathetic drive secondary to hypercarbia and, to a lesser extent, on increased pressure on the abdominal aorta. Cardiac output falls when the intra-abdominal pressure exceeds 20 mm Hg. Arrhythmias are common with CO_2 insufflation, the most frequent being bradycardia due to reflex vagal stimulation. This is prevented by premedication with atropine. Other arrhythmias are mainly due to inadequate ventilation, especially when the patient is in the Trendelenburg position. They include bigeminal rhythm, ventricular ectopic beats and ventricular tachycardia.

CO_2 insufflation of the peritoneal cavity is also accompanied by a fall in the arterial pH and pO_2, a rise in the pCO_2 and a fall in the serum chloride level. The respiratory acidosis is less pronounced if muscle relaxation and controlled ventilation are used.

Cardiac Complications

The most serious complication is cardiac arrest due to ventricular fibrillation. The reported incidence of this complication of laparoscopy is 0.2 per 1000. The important risk factors are pre-existing ischaemic heart disease and inadequate ventilation (anaesthetic mishap). When encountered, immediate desufflation of the pneumoperitoneum is undertaken with removal of the cannulae and the cardiac resuscitation measures instituted.

Gas Embolism

Gas embolism is rare with CO_2 in view of the solubility of this gas. In animal experiments, volumes larger than 1.0 l injected intravenously are required before the cardiac output falls significantly. Nonetheless, instances of CO_2 embolization are recorded. Often these are the result of misplacement of the Veress needle either in the body of the uterus or liver, although instances with no apparent evidence of direct vascular injuries have been reported. Gas embolism is best diagnosed by precordial Doppler ultrasound (millwheel murmur). It is prevented by careful insertion of the Veress needle and ensuring that the tip lies free in the peritoneal cavity. In addition, insufflation of the peritoneal cavity should proceed slowly with a flow rate which does not exceed 1.0 l CO_2 per minute.

Mediastinal Emphysema and Pneumothorax

Mediastinal emphysema is common, especially in patients with hiatus hernia and is invariable during perioesophageal laparoscopic surgery when it is often accompanied by surgical emphysema of the neck and upper chest wall. It is of little consequence and needs simple observation. Pneumothorax occurs much less frequently and is due to rupture of pre-existing bullae. Unless small, it is treated by intercostal tube drainage.

Penetrating Injuries and Haemorrhage

These may be caused by the Veress needle or the initial trocar and cannula insertion. The latter injuries are more extensive. Often the cause is faulty technique. These injuries are more commonly encountered in thin individuals in whom the space between the abdominal wall and important structures such as the aorta measures only a few centimetres, and in patients with adhesions due to previous surgical intervention. The prevention and management of these lesions are discussed in Chap. 7.

Wound Complications

Wound complications include bruising, infections (which are infrequent – 0.5 per 1000 – and late), leakage of ascitic fluid and hernia formation. Although wound infections are usually minor, instances of necrotizing fasciitis have been reported. Leakage of ascitic fluid occurs in patients with ascites if the fascial layer of the subumbilical wound has not been sutured. It requires active intervention by direct suture of the fascial layer to stop the leakage and to prevent infection of the ascites.

Omental prolapse may result if the cannula is removed too rapidly when a tongue of omental tissue is dragged into the wound. If unnoticed, this may lead to intestinal obstruction and hernia formation. A more serious complication develops following partial entrapment of a loop of small intestine in the depths of the wound, leading to the formation of a Richter's hernia. This complication is rare and the author has encountered it only once in a series of 2500 laparoscopies.

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15 Laparoscopic Appendicectomy

A. PIER and F. GÖTZ

Introduction

Morton performed the first successful methodical appendicectomy with drainage of an abscess in 1887 [1]. In 1889, McBurney [2] published his first studies of acute appendicitis. From then on, the operative technique of appendicectomy developed rapidly. In 1902, Ochsner [3] published the first monograph on the diagnosis and therapy of appendicitis. In the following decades appendicectomy became established as the standard treatment for acute appendicitis.

A modification of Semm's [4] laparoscopic appendicectomy was adopted by our department of surgery in May 1987. Standardized and established by Götz [5–7] this technique enables us to treat all stages of appendicitis.

Indications

Epidemiological studies performed by Lichtner and Pflanz [8] and Pflanz [9] at the beginning of the 1970s showed that the mortality rate for acute appendicitis, at 3.3 deaths per 100000 inhabitants per year, was three times higher in Germany than in comparable countries like Great Britain, Sweden or the United States.

The number of complications increases with the degree of severity of the appendicitis at the time of operation. Among the complications are wound infection, suppuration, wound dehiscence due to infection, intra-abdominal abscess, severe purulent peritonitis caused by appendix perforation, and postoperative strangulating obstruction.

Definitive diagnosis can be difficult; misdiagnoses can be caused by abnormal positions, caecal mobility and pregnancy. Moreover, basal pleurisy, right renal and ureteral colic, acute cholecystitis, Meckel's diverticulitis, terminal ileitis and caecal carcinoma can all be confused with appendicitis. In female patients, diseases of the right pelvic adnexa, e.g. salpingo-oophoritis, endometriosis and ruptured ovarian cyst, add to the difficulties of differential diagnosis.

Appendicectomy carries all the dangers of abdominal surgery. Al-Suleimani [10], Pieper [11] and Tuchmann [12] report that even false diagnoses like adnexitis or endometriosis incur mortality of 0.25 per 100000. The misdiagnosis rate for acute appendicitis is substantial: Thomas and Mueller [13] reported 20%–30%, Lewis [14] stated 20%, Leape and Ramenofsky [15] gave 5%–15% and Hontschik [16] reported 10%–20%. Deutsch [17] reported that over one third of unnecessary appendicectomies performed in women of child-bearing age are avoidable by emergency diagnostic laparoscopy. Aside from the cost-saving aspect, this practice reduces the occurrence of postoperative complications.

Patient Selection

The clinical diagnosis of acute appendicitis is based on the combination of clinical signs and symptoms, e.g. McBurney's sign, tenderness on percussion or Blumberg's sign in the right lower abdomen, muscular guarding and rigidity, psoas spasm, Rovsing's sign, anorexia, nausea, vomiting, recto-axillary temperature difference and leucocytosis.

Severe acute appendicitis is characterized by a more fulminant course and marked physical pain. Moreover, all patients suffer additionally from pain in the right iliac fossa. In the case of subacute appendicitis one normally finds the same clinical symptoms but in a less severe form. Chronic appendicitis features recurrent symptoms of variable intensity with symptom-free intervals.

Very obese patients are excluded from the laparoscopic/endoscopic method of operation. We perform the appendicectomy in a conventional manner if no surgeon experienced in the laparoscopic/endoscopic procedure is available or if the patient has not given consent to this relatively new method of operation.

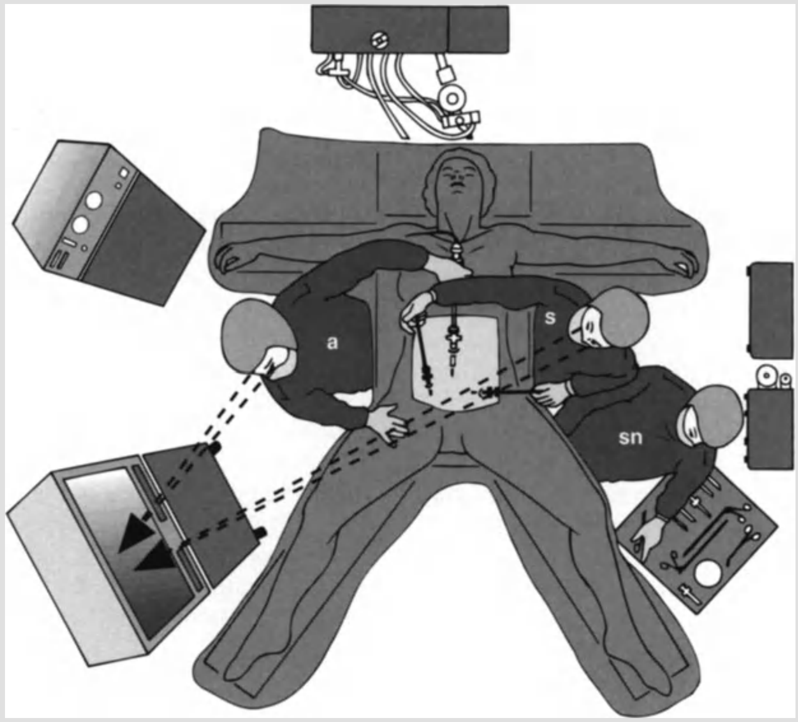


Fig. 15.1. Positioning of staff and apparatus. *s* surgeon; *a* assistant; *sn* scrub nurse

Preoperative Preparation

The first preparatory step is detailed instruction of the patient. It has to be emphasized that conversion to laparotomy may be necessary. As general anesthesia is required, all related risks are evaluated. After depilation the abdominal skin, particularly that of the navel, is cleaned thoroughly. When evacuated by catheterization, the urinary bladder is unlikely to disturb visual exploration or to be perforated.

Positioning of Patient

The patient is operated upon in the lithotomy position – Trendelenburg's position with a slight tilt to the left. The operation site is disinfected and covered with sterile drapes.

Instrumentation

The following items are necessary for endoscopic appendicectomy:

1. Video camera
2. Hopkins straight endoscope (10.5 mm)
3. Hook scissors
4. Grasping forceps
5. Atraumatic exploring probe
6. Bipolar forceps
7. Roeder loop
8. Cable for light source
9. Trocar (11 mm) for scope
10. Working trocar (11 mm)
11. Appendix extractor
12. Working trocar (5.5 mm)
13. Applicator for Roeder loop
14. Veress needle
15. CO_2 tube
16. Cable for bipolar forceps

Positioning of Staff and Apparatus

Staff and apparatus should be positioned as shown in Fig. 15.1.

Operative Steps

Creation of Pneumoperitoneum and Laparoscopic Inspection

For trocar placement see Fig. 15.2.

The transumbilical puncture of the abdomen is performed with a Veress needle; the correct position of the Veress needle is checked by injecting 5–10 ml of a 0.9% NaCl solution as well as by performing an aspiration test and a "hanging drop test". The pneumoperitoneum is created with an electronic CO_2 insufflator. When the correct intra-abdominal pressure of 12–14 mmHg has been achieved, the Veress needle is removed. A stab incision is made at the lower aspect of the umbilicus; the trocar accommodating the scope (adults 11 mm, children 7 mm) is inserted by the "Z"-track method according to Semm [4].

The first diagnostic inspection is made with the inserted Hopkins straight endoscope in order to exclude iatrogenic intra-abdominal injury. A second stab incision (Fig. 15.2) is then made in the left lower abdomen under visual control and the working trocar (5.5 mm) is inserted. The entire abdomen is thoroughly inspected with palpating probe. For this purpose the patient is moved to lie in the head-down lateral position slightly displaced to the left. Through the magnifying laparoscope, the inflammatory stage of the appendix can be identified macroscopically (Fig. 15.3).

Technique of Endoscopic Appendicectomy

Another working trocar (11 mm) is inserted under visual control into the right lower abdomen (Fig. 15.2). The tip of the appendix is grasped with a forceps (Figs. 15.3, 15.4). Skeletonization of the appendix is performed by traction on the mesoappendix with an atraumatic forceps. The mesoappendix including the appendicular artery is coagulated with a bipolar coagulation forceps (Figs. 15.5, 15.6).

With dissecting scissors, the coagulated tissue is transected until the base of the appendix is reached (Fig. 15.7). The base of the appendix is ligated with a Roeder loop (Figs. 15.8, 15.9) and then coagulated distal to the ligature (Fig. 15.10). The coagulation of the appendix results in the occlusion of the lumen, and the

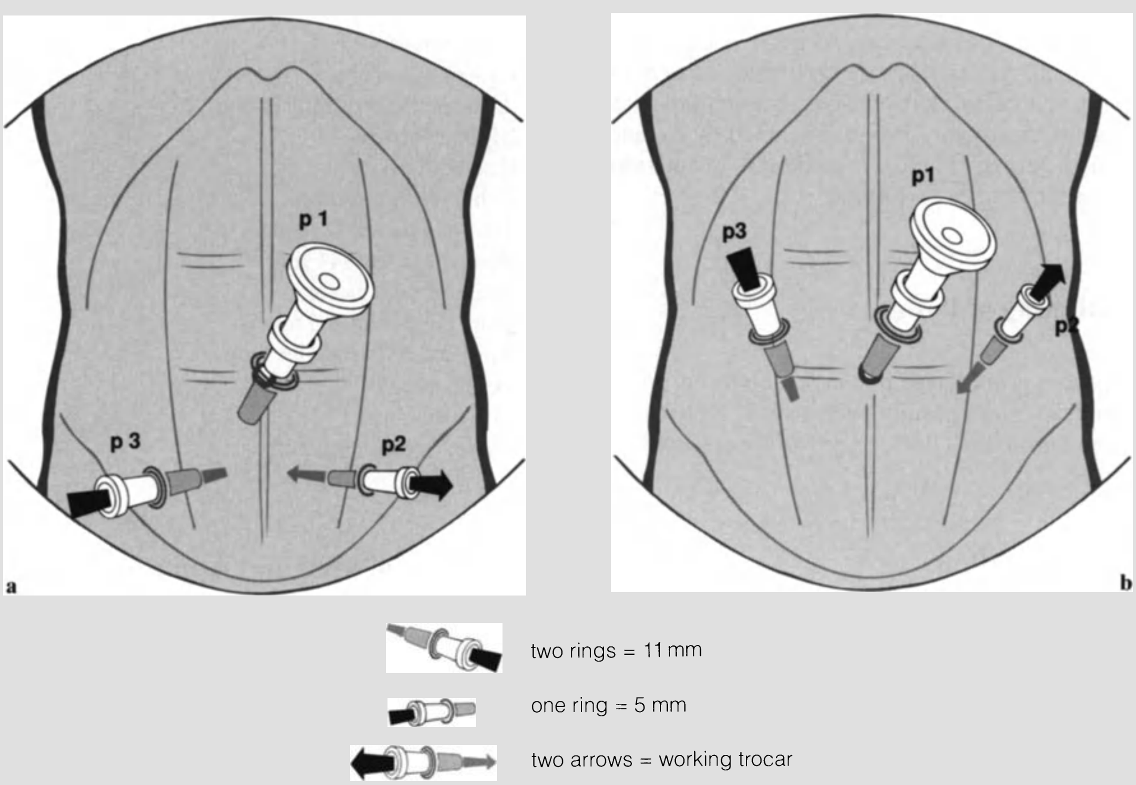


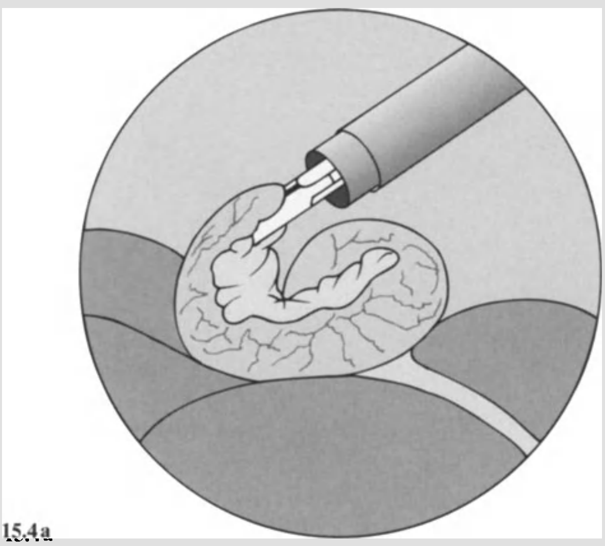
Fig. 15.2. **a** Trocar placement in the standard situation. *p1*, Optic trocar; *p2*, working trocar; *p3*, extraction trocar. **b** Trocar placement after endoscopic diagnosis of elevated caecum

Fig. 15.3. Appendix with signs of acute inflammation and typical localization

Fig. 15.4. **a** Grasping the appendix close to the tip. **b** Endoscopic picture

Fig. 15.5. **a** Bipolar coagulation of the mesentery close to the tip of the appendix after exposure by rotation of the grasping forceps. **b** Endoscopic picture

15.3



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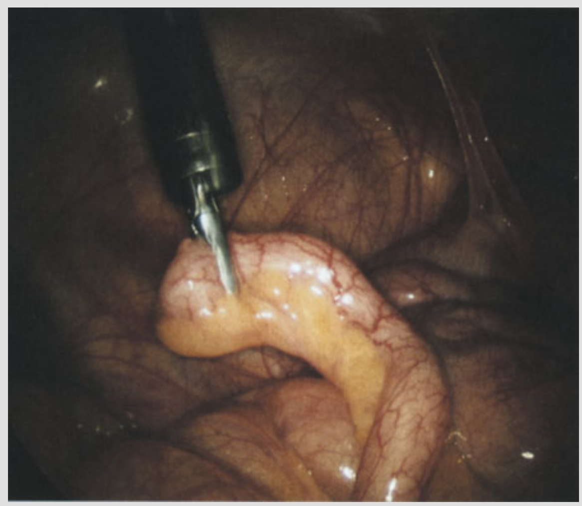

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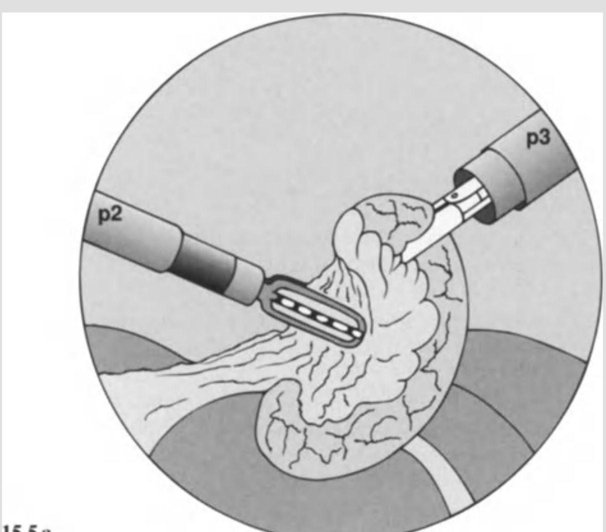

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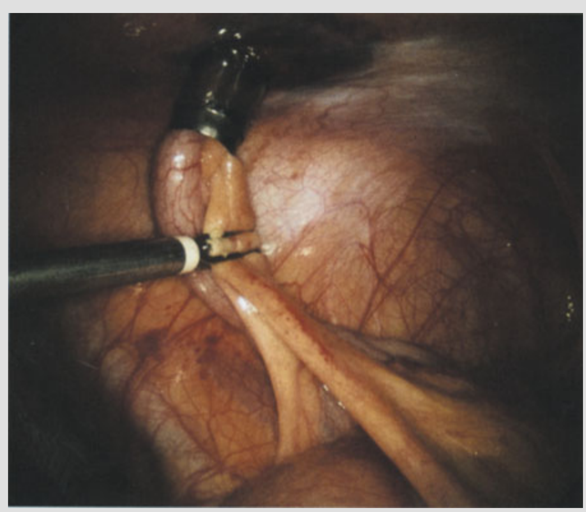

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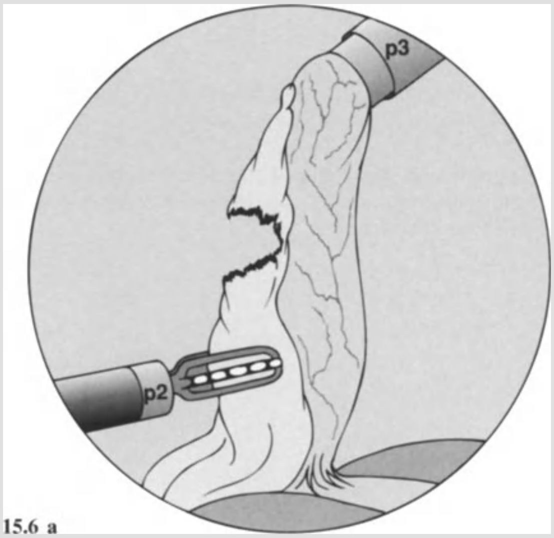

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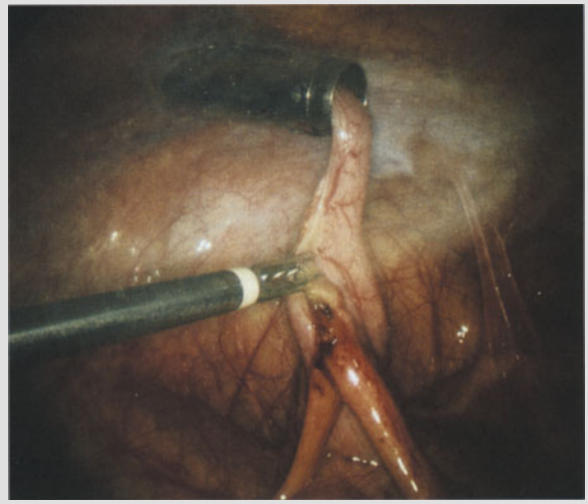

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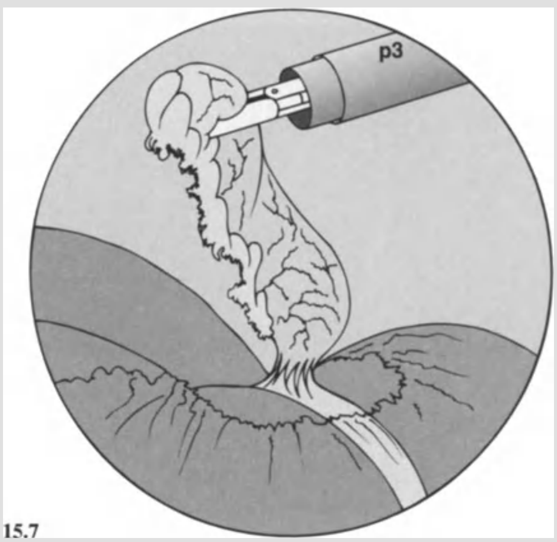

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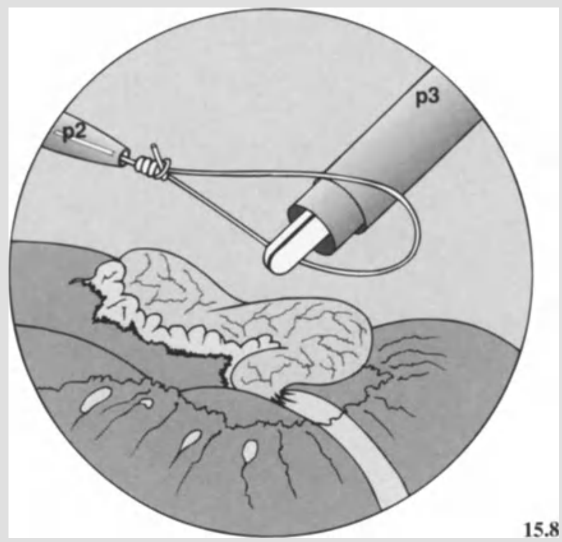

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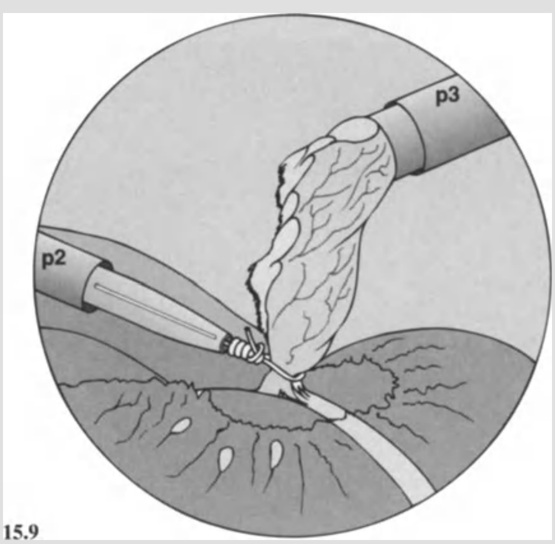


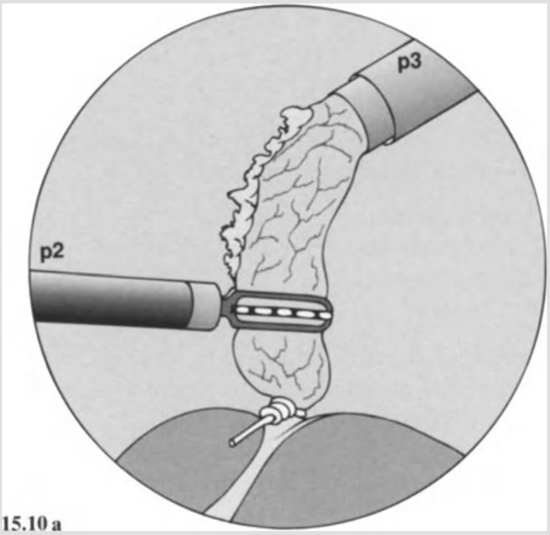
15.9

Fig. 15.6. **a** Second step of bipolar coagulation of the mesentery in the middle third of the appendix. **b** Endoscopic picture

Fig. 15.7. The junction of the appendix with the caecum is precisely dissected

Fig. 15.8. For ligation of the appendix stump a pretied Roeder loop is introduced using trocar port 2 and pushed over the extractor trocar port 3

Fig. 15.9. The appendix is pulled into the extractor and the loop jammed close to the basis of the appendix



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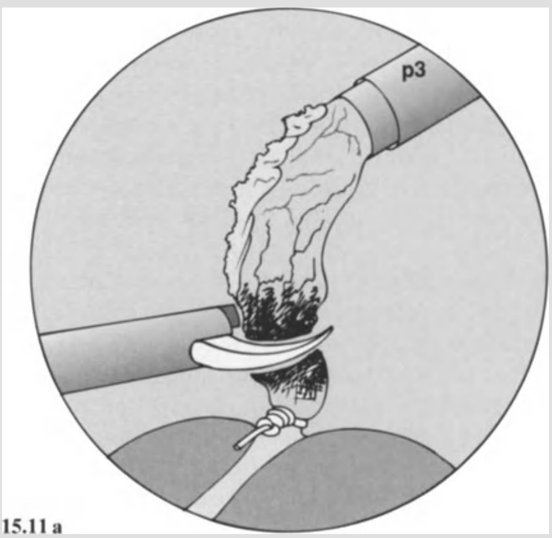
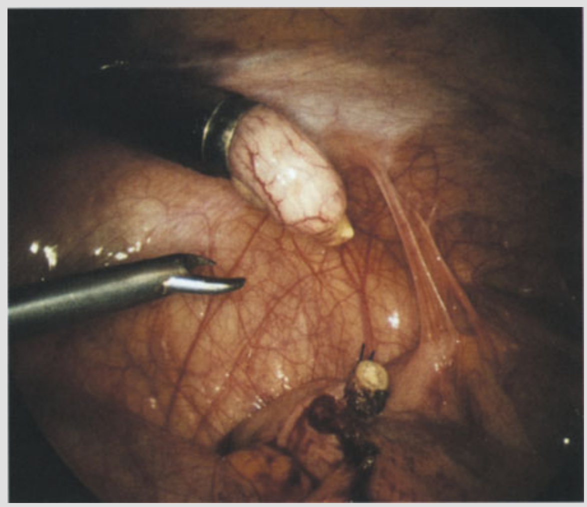


15.11 a



b

Fig. 15.10. **a** Bipolar coagulation of the appendix 5–7 mm from the ligature. **b** Endoscopic picture: caecum not well exposed

Fig. 15.11. **a** The appendix is cut in the centre of the coagulated area. **b** The appendix is pulled into the extractor

high temperature of the coagulation assures sterility. The appendix is transected across the coagulation area with scissors (Fig. 15.11). The isolated appendix is removed through the appendix extractor without contact with the abdominal walls (Fig. 15.12). The stump of the appendix is then disinfected with an iodine swab (Fig. 15.13). If necessary, the operative site can be washed and drained.

The operative field is inspected for haemostasis. Under visual control the trocars are removed and the peritoneum is desufflated. The surgical procedure is completed by the closure of fascia by means of a subcuticular suture, stapled skin closure or sterile adhesive tapes.

In summary, the laparoscopic appendicectomy as modified by Götz differs from Semm's method in the following respects:

1. Fixation of the appendix tip
2. Ligature of the appendicular artery
3. Coagulation in the resection area of the appendix
4. Number of appendix ligatures
5. Invagination of appendix stump
6. Number of stab incisions
7. Trocar placement

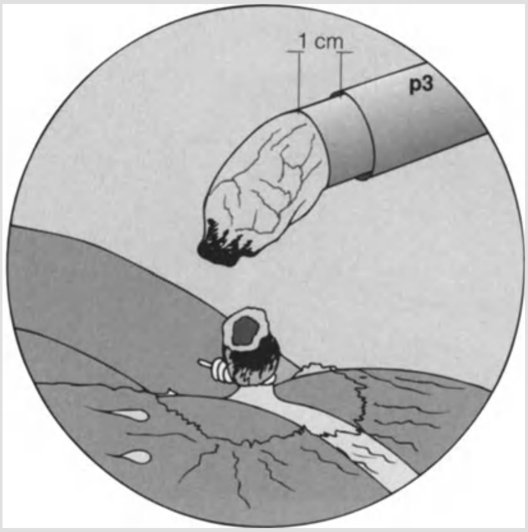


Fig. 15.12. During extraction the tip of the extractor tube should project beyond the port, so that the port is not contaminated

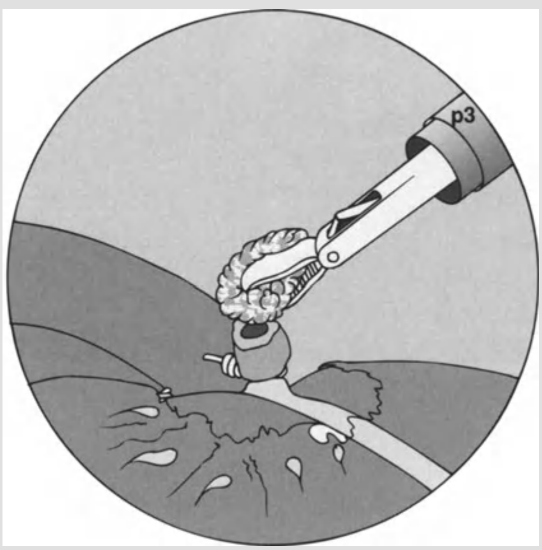


Fig. 15.13. Disinfection of the appendix stump via the extractor

Procedure in Case of Atypical Position of Appendix

In approximately 45% of cases we have found the appendix in an atypical position:

- Elevated caecum
- Displacement into small pelvis with mobile caecum
- Retrocaecal position
- Situs inversus

Laparoscopic appendicectomy in the case of elevated caecum is the exception, especially with a subhepatic position of the appendix.

Appendicectomy with Elevated Caecum

After correct insertion of the trocar accommodating the scope as previously described, diagnostic inspection is performed. If atypical position of the appendix is confirmed, for example in the right upper abdomen, the subsequent trocars should no longer be positioned as indicated in Fig. 15.2 a; rather, they should be placed more proximally at the level of the umbilicus (Fig. 15.2 b).

If clear visual identification of the situs is not possible, a 5.5 mm working trocar is inserted into the left lower abdomen. With the help of a palpating probe the position of the appendix can be ascertained. In the case of elevation of the caecum, it is recommended to place an 11 mm trocar on the right side at the level of the umbilicus for appendix extraction (Fig. 15.2 b). Contrary to the procedure performed when the appendix is in its typical position in the right lower abdomen, a reverse Trendelenburg position (elevated head) with slight lateral displacement to the left is recommended.

The appendix can then be skeletonized as already described withdrawn from the abdominal cavity into the appendix extractor. The base of the appendix is ligated with a Roeder loop and coagulated. A sharp transection of the base is performed, followed by disinfection with an iodine swab.

Retrocaecal Position

If the appendix cannot be identified with the palpating probe, the position of the patient is changed (head down, slightly to the left). It is recommended to proceed to the caecum along the taenia libera in a caudal direction. The appendix can usually be identified by

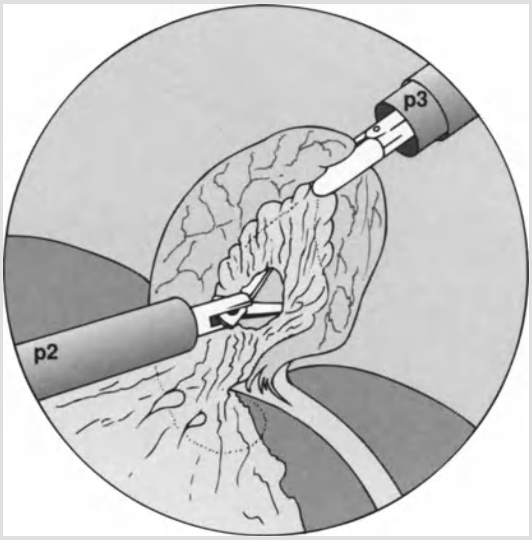


Fig. 15.14. Fenestration of the mesoappendix in the case of retrograde dissection in retrocaecal appendix

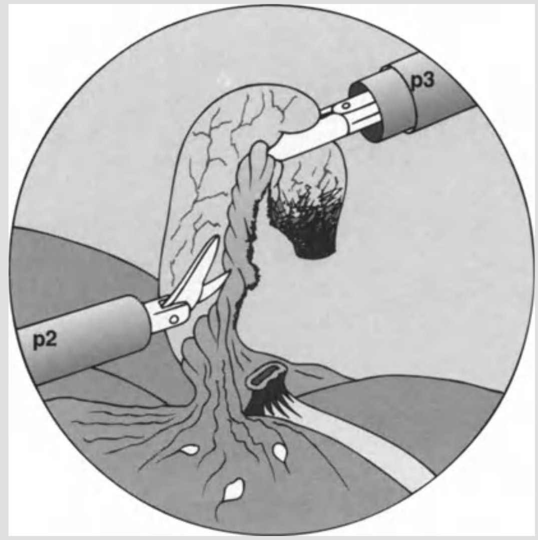


Fig. 15.15. Cutting of the coagulated area

turning the caecal pole to the left. In such a situation the appendix is often coated with adhesions and the tip of the appendix is invisible, making the operation more difficult. In this case a completely different procedure for the dissection of the appendix has to be applied: the retrograde resection. The trocar placement used for this procedure is the same as applied to an anterograde resection (Fig. 15.2 a).

Retrograde Dissection

For trocar placement see Fig. 15.2.

With the palpating probe the taenia libera is once again identified up to the base of the appendix. An atraumatic 5.0 mm grasping forceps is then inserted through the right appendix extractor; the appendix is grasped ca. 1–2 cm above the base and kept under tension. The fenestration of the poorly vascularized area of the mesoappendix is performed near the base with scissors inserted through the left 5.5 mm working trocar (Fig. 15.14). This dissection has to be performed with great care so that no bleeding occurs from the appendicular artery. In this respect, it is helpful to incise at first only the peritoneal lining of the mesoappendix and then to push the tissue aside – carefully and bluntly – with a dissecting forceps.

If the window has been created, the remaining bridge of the mesoappendix with the appendicular artery is coagulated with an HF bipolar coagulation forceps inserted through P3; afterwards, a sharp transection is made in the coagulation area (Fig. 15.15). The base of the appendix is thus completely isolated and coagulated repeatedly with short impulses at a safe distance of 1 cm to the caecum.

Care has to be taken that the tissue has time to cool down between the impulses, in order to avoid thermal destruction of the tissue at the ligature.

At this point it should be mentioned that a certain amount of experience is needed to choose the correct and safe laparoscopic distance from the caecum. Therefore, it is absolutely necessary to perform a precise circular dissection of the base of the appendix, taking into consideration the anatomical variants of the appendicular artery (Fig. 15.16) which were pointed out by Stelzner and Lierse [18].

After the transection of the appendix near its base in the coagulation area, the prepared Roeder loop carrier with the Roeder loop is inserted into the abdomen through P2 and placed over the free base. The grasping forceps having been used through P3 to pull the appendix, is now used to grasp the appendix stump inside the above placed loop (Fig. 15.17). With the loop carrier, the Roeder loop is placed near the base and after locking the pretied knot by the push rod, the suture can be transected and removed from the abdominal cavity.

The further delivery of the appendix is performed with a grasping forceps inserted through the appendix extractor. The free end of the appendix having been closed by coagulation, it is grasped and pulled – in a retrograde manner – into the appendix extractor, so

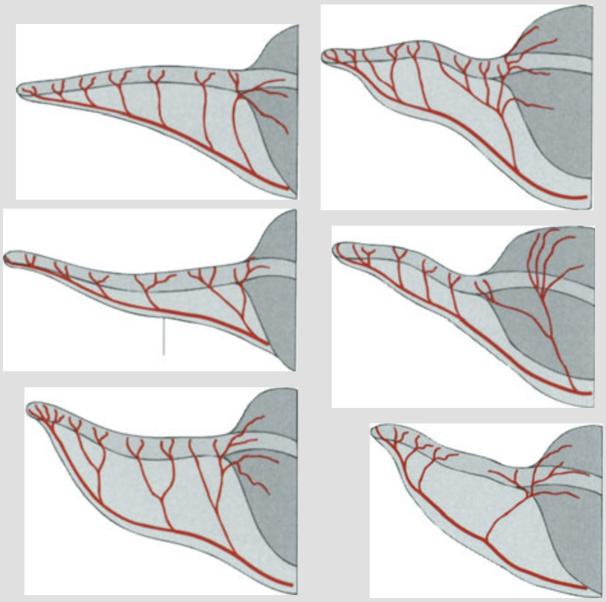


Fig. 15.16. Variations of the anatomy of the appendicular artery (by Stelzner)

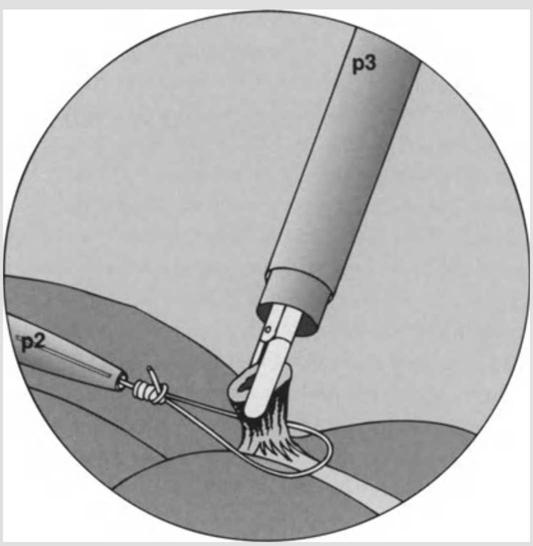


Fig. 15.17. Loop placement after retrograde dissection of the appendix

that the mesoappendix or the adhesions are contracted. The mesoappendix is coagulated and sharply transected so that the appendix is skeletonized in a reversed manner (Fig. 15.18). The appendix isolated, can be removed with the distal end first through the appendix extractor without touching the abdominal walls.

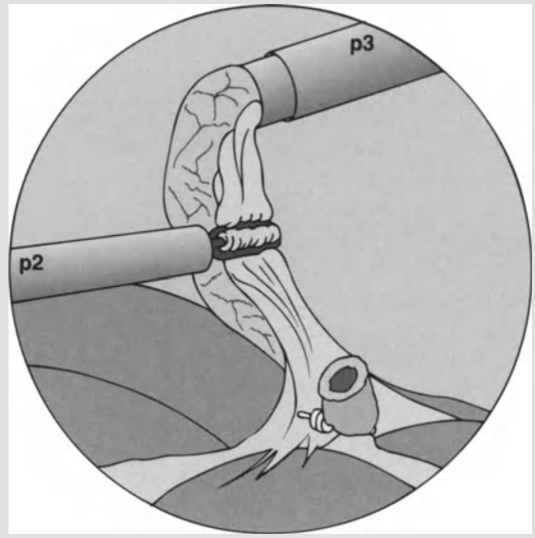


Fig. 15.18. Technique of retrograde dissection

Afterwards, the appendix stump is disinfected with iodine and placed in the retrocaecal position. The trocars are removed under visual control.

Perityphlitic Abscess

For trocar placement see Fig. 15.2.

As already described in literature, a perityphlitic abscess occurs very seldom nowadays. However, if such an abscess is discovered during laparoscopy, we recommend the following procedure:

Under no circumstances must the patient be positioned head down during the irrigation/aspiration process. This prevents transmission of germs into the upper abdomen with subsequent contamination and risk of subhepatic or subphrenic abscess formation.

Instead, the patient should be placed in a 10° reverse Trendelenburg position, slightly displaced to the left. With the palpating probe – inserted through P2 – the bowel walls covering the abscess are carefully pushed away. At the same time, the suction device is kept ready above the right appendix extractor. As soon as the first pus escapes, it can be aspirated. The suction device can be inserted through a small opening into the abscess cavity. Then the pus is carefully aspirated and the cavity is irrigated. The cavity is then opened in order to insert a Robinson drain through the appendix extractor into the right lower abdomen.

The Robinson drain is advanced slowly into the site. The catheter is fixed with a grasping forceps inserted through P2. The trocar including appendix extractor can then be removed from the right lower abdomen.

We recommend local administration of an antibiotic, which should be inserted directly into the site through the remaining 5.5 mm trocar. Moreover, we recommend perioperative systemic administration of an antibiotic for at least 5 days.

The drain should remain in place for at least 3–5 days postoperatively. Serosanguineous material will discharge through the drain for several days after the operation. The quantity and the composition should, of course, be recorded in the medical report.

Phlegmonous/Gangrenous Appendicitis

For trocar placement see Fig. 15.2.

In the case of phlegmonous/gangrenous appendicitis a turbid, serous exudate can usually be seen in the Douglas pouch or in the area of the caecal pole when performing the diagnostic inspection with the help of the palpating probe. The appendix and the terminal ileum are matted.

Very often the anatomy is obscured, so that the discoloured tissue structure has to be exposed with the help of a palpating probe. The surgeon should realize that these altered appendices, a thumb breadth in thickness, cannot be removed from the abdominal cavity through a 10 mm appendix extractor without touching the abdominal walls.

For such cases we have developed a 15 mm or 20 mm appendix extractor. The incision in the right lower abdomen is slightly enlarged and the 10 mm extractor is replaced with the 15 mm or 20 mm extractor. The suction device is inserted through the larger extractor in order to aspirate the serous liquid from the abdominal cavity of the patient, who has been placed in a reverse Trendelenburg position. Then the appendix is grasped over a wide margin – if possible – at the tip and pulled into the extractor sleeve. As far as the mesoappendix can be identified, coagulation is performed with an HF coagulation forceps inserted through P2 (Fig. 15.19) followed by sharp transection. If the base of the appendix is exposed, it is coagulated first, in contrast to the method of appendectomy described above, in order to avoid an escape of contaminated material from the transected appendix (Fig. 15.20).

Then the tip of the appendix is freed and the Roeder loop carrier together with the loop is inserted through P2. The loop is placed around the appendix grasping forceps, which is still in the abdominal cavity.

Fig. 15.19. Procedure in phlegmonous appendicitis. Coagulation of mesoappendix

Fig. 15.20. Transection of the coagulated appendix

The Roeder loop can be placed near the base below the coagulation area; the preset breaking point of the push rod is broken so that the knot can be tightened carefully (Fig 15.20).

The scissors may be inserted into the abdominal cavity through the same working trocar (P2) in order to cut the Roeder loop ca. 1.5 cm above the knot. This distance is appropriate and prevents inadvertent loosening of the pretied knot.

With the same scissors the appendix can be transected near the base across the coagulation area (Fig. 15.20). As far as this extraction technique is concerned, it is important to ensure that the appendix extractor sleeve overlaps the trocar sleeve by 5 mm inside the abdomen. In this way contamination of the trocar sleeve can be avoided, as it touches the abdominal wall at the end of the procedure when the trocars are removed from the site under visual control.

Then the site is thoroughly irrigated and aspirated with the suction device inserted through the right appendix extractor. Care has to be taken that the patient is not placed in a head down position. The remaining appendix stump is disinfected with an iodine swab. Afterwards, an antibiotic is administered locally.

After final control of haemostasis, a 12-F Robinson drain is inserted through the right appendix extractor to the site. In order to fix the Robinson drain when removing the extractor, a grasping forceps is inserted through P2 – as described above – to grasp the drainage tube at the tip so that the trocar can be removed under visual control. In these cases we administer systemic antibiotic therapy for at least 5 days postoperatively. The drainage tube is removed after 3–5 days.

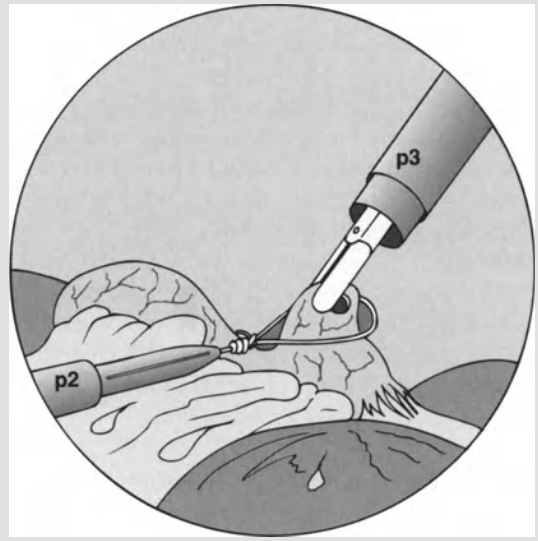


Fig. 15.21. Provisional closure of perforation site in case of perforated appendicitis

Perforated Appendicitis

For trocar placement see Fig. 15.2.

Fortunately, acute appendicitis is mostly diagnosed correctly and in time nowadays, so that perforated appendicitis has become a rather rare diagnosis. Nevertheless, we have treated a number of perforated appendices laparoscopically.

During the initial diagnostic survey, fibrin deposits can be recognized in the lower abdomen. In addition, the whole lower abdomen including the parietal peritoneum are in a highly inflammatory condition. Often the perforation is covered and appears as a conglomerate tumor. Serosanguineous liquid is found in the Douglas pouch and in the region of the caecal pole.

As in the procedure performed in the case of gangrenous appendicitis, we first try to clearly identify the site with the help of the palpating probe inserted through P2. It is often possible to expose the site of perforation. Thereafter the surgeon tries to identify the base of the appendix. If the site of perforation is situated near the tip of the appendix, and if the tip tears off when pulling it into the inserted 20 mm trocar, a Roeder loop is placed on the residual appendix in order to close the lumen (Fig. 15.21). The appendix is then grasped with a grasping forceps inserted through the right appendix extractor and pulled into the extractor, so that the dissection of the appendix can be continued. As soon as the base of the appendix has been reached, it is coagulated, then the Roeder loop is placed across it. The operating area is of course irrigated. Intensive lavage of the abdominal cavity with 0.5%–2.0% taurolin solution has proved beneficial in these patients.

Afterwards, an antibiotic is injected locally with the help of an injection cannula inserted with the Roeder loop carrier through the left working trocar.

Finally, one or two Robinson drains are placed in the operation area in the right lower abdomen, and another drain is placed in the Douglas pouch.

Systemic antibiotic therapy is administered for 5 days. The drains can be removed after 3–5 days.

Surgeons with little experience in laparoscopic surgery should not hesitate to convert to laparotomy if difficulties are encountered in these complicated cases.

Results

Patients

The average age of our patients was 18 years, with a range of 2–89 years. Fifty-nine percent of the patients were female, 41% male. Some 11.3% of our patients were females aged between 19 and 25 years. The age range of the male patients was 6–18 years.

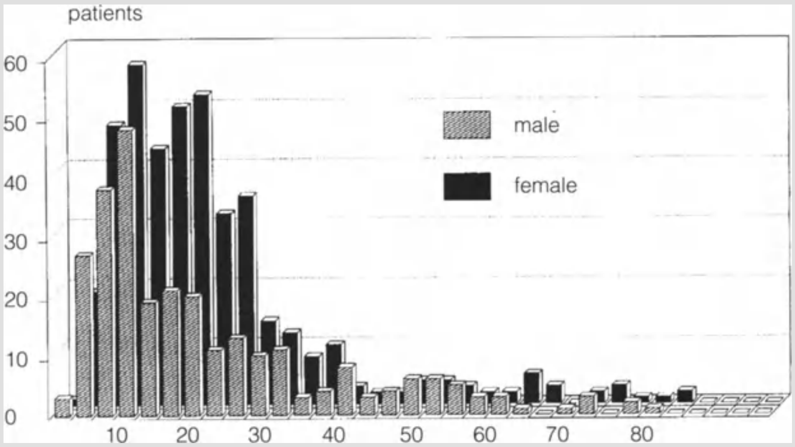


Fig. 15.22. Age and sex distribution

In the period from January to May 1987 we performed appendicectomy in 37 patients according to De Kok's [19] technique, i.e. the endoscopic operation was performed in the "open abdomen". Subsequently, during the period from May 1987 to July 1990, we performed appendicectomy in 678 patients.

Methods of Operation

A total of 625 operations in all stages of appendicitis were performed with the laparoscopic/endoscopic method of operation, irrespective of the anatomical position of the appendix (Fig. 15.22). An additional 39 patients underwent conventional open appendicectomy according to the method of McBurney. During the initial phase intra-operative conversion from laparoscopy to the conventional method of operation was necessary in 14 patients (Fig. 15.23).

Twenty-two of the 625 laparoscopic-endoscopic appendicectomies were performed using Nd:YAG or CO_2 lasers (Fig. 15.24).

Histopathological Findings

The histopathological findings of 625 examined specimens were as follows:

- Acute appendicitis 431 (69%)
- No changes 88 (14%)
- Subacute appendicitis 75 (12%)
- Recurrent appendicitis 19 (3%)
- Hyperacute appendicitis 12 (2%)

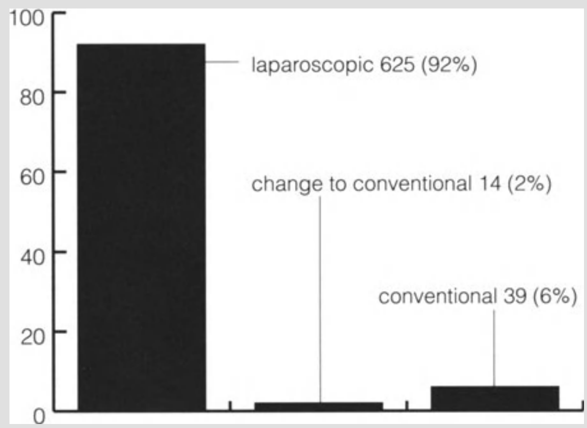


Fig. 15.23. Techniques of operations

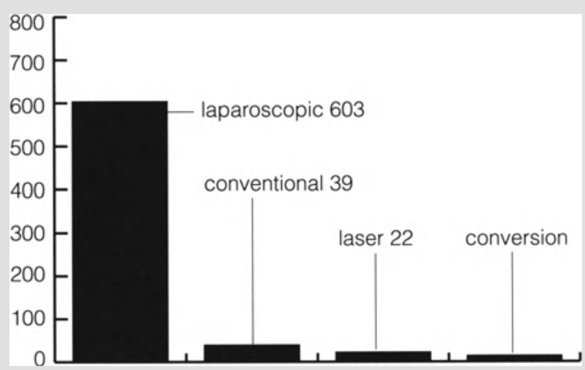


Fig. 15.24. Methods of operation for appendicectomy

Secondary Findings

Intra-operatively we found the following important secondary findings:

Hydatids/ovarian cysts 56
Indirect inguinal herniae 43
Chocolate cysts 5
Carcinoid tumors of appendix 3
Adhesion to ovary 1
Diverticulum of the caecal wall 1
Meckel's diverticulum 1
Mucocoele of appendix 1

Operating Time

For the first 50 procedures we needed an average operating time of 38 min. After this phase the operating time decreased to 15–20 min, comparable to the conventional appendicectomy according to McBurney [2].

Complications

Complications occurred in seven cases (1%). In two cases of perforated and phlegmonous appendices, laparotomy was needed to treat postoperative abscess formation. After completing this survey, one more patient developed a postoperative abscess with paralytic ileus and required laparotomy.

The stump was insufficiently coagulated only once. In this particular patient, we had coagulated the appendix too close to the Roeder loop ligature, which would not guarantee safe sealing of the lumen. Therefore, we stress that the loop and the coagulation area must be at least 6–7 mm apart.

Bleeding is often overestimated because of the magnification of the camera system. Only during the initial phase of our work did we convert to conventional laparotomy because of what we thought was laparoscopically uncontrollable bleeding (three cases, including one rupture of an ovarian artery with subsequent oophorectomy).

Nevertheless, bleeding is a possible complication that can be handled during a laparoscopic procedure by the usual means of surgical haemostasis such as ligature, clip application, or electric or thermal coagulation.

In 14 patients (2.1%) an infection of the stab wound occurred at the lower aspect of the umbilicus. However, this did not require longer hospitalization; it was treated with neomycin sulphate-bacitracin powder and ethacridine lactate dressings.

In total, 23% of patients complained of subphrenic pain and 71.1% of scapular pain, mostly on the right side. The combination of subphrenic and scapular pain occurred in 19.2% of patients.

Control of pain by analgesics the morning after the operation was required in 7.9% of the laparoscopically treated patients compared to 31% of the conventionally operated patients.

After laparoscopic appendicectomy 4.7% of patients had pyrexia on the first postoperative day. The average was 38.1° C (axilla).

The vast majority of patients (95%) were ambulant on the day of operation and all became so by the third postoperative day.

Conversion to Open Surgery

Out of 639 laparoscopic-endoscopic appendicectomies, including those performed during the initial phase, 14 were converted to the open conventional method of operation according to McBurney [2]. This was necessitated by the following complications or anatomical abnormalities:

Abnormal position	4 (0.6%)
Abscess	3 (0.5%)
Bleeding	3 (0.5%)
Adhesions	4 (0.5%)
Perforation	2 (0.2%)

In two patients we had to convert to open surgery because of the combination of adhesions and bleeding from the appendicular artery, or adhesions and abnormal position. On only one occasion (in the initial phase) did we give up the endoscopic approach for a perforated appendix and convert to an open operation.

In 39 patients, we decided at the beginning to use the conventional open method according to McBurney, because either a trained surgeon was absent or the patient was unwilling to undergo a laparoscopic appendicectomy because it was considered a new procedure.

Morbidity and Mortality Rate

The morbidity rate for the series was 0.7%. There were no postoperative deaths.

Discussion

Contrary to the initial notion that laparoscopic appendicectomy could only be performed for chronically inflamed or fibrosed appendices, we have successfully applied this method of operation to all stages of appendicitis. Even obesity is no obstacle to the laparoscopic approach, as longer trocars can be used.

Regarding subhepatic abscess formation, we think that the head-down position of the patient during the wash/drain process caused contamination of the upper abdomen. Since we abandoned the head-down position during the wash/drain process, abscess formation has been a rare occurrence.

The total complication rate is 1%. Laparoscopic appendicectomy is not attended by any increased intra-operative or postoperative morbidity compared to the conventional operation as reported by Lewis [14] in a study of 1000 patients undergoing the open procedure. In this study the complication rate was 12.8%, largely due to wound infection.

Antibiotics were not given prophylactically. According to Giehl [22] these patients should be covered by pre-operative antibiotics, but in our view this would make diagnosis more difficult.

As far as duration of hospital stay is concerned this is reported by Lewis [14] to average 9.1 days after the conventional procedure, whereas the mean stay after the endoscopic operation is 5.8 days. We are convinced that the hospitalization time can be reduced further, to 2–4 days, in the near future. The early mobilization is due to the minimally invasive method of operation. There is less peritoneal trauma, no evisceration of the ileum and less irritation of the caecum.

The average operating time, now 18 min, compares favourably with the operating time of 20–25 min for the conventional method.

A negative effect of the laparoscopic method is the postlaparoscopic pain syndrome. Some 71.8% of the patients suffered from right-sided scapular pain or subphrenic pain on the first and second postoperative days. In their studies, Riedel and Semm [23] assumed – in contrast to Kröhl [24] – that the dissolution of CO_2 gas in the fluid content of the peritoneum followed by dissociation accounted for the symptoms. With the help of infrared spectography, however, we were able to show that the symptoms were related to the volume of the residual gas irritating the peritoneal lining of the diaphragm and the phrenic nerve.

For this reason, complete postoperative CO_2 desufflation has to be performed. We achieve this by compressing the abdomen in the relaxation phase after removal of the cannulae. For the elimination of the remaining gas, Riedel and Semm [23] insert a catheter which is placed subdiaphragmatically in the right upper abdomen to promote postoperative drainage for 6 h. Our observations clearly show that a definite reduction of the postlaparoscopic pain syndrome can be achieved by the method we use.

Studies reported by Haag [25] clearly show that intra-abdominal adhesions occur more frequently after conventional appendicectomy. Haag observed that 68% of 965 patients who underwent conventional appendicectomy developed adhesions. The aetiology of chronic lower abdominal pain – adhesions after appendicectomy or undiagnosed gynaecological disease – remains unresolved.

Haemorrhage from the appendicular artery was one of the reasons for conversion during the initial phase. We now consider that the magnifying effect of the laparoscope played an important role in this decision. The inexperienced surgeon can be misled into thinking that minor haemorrhage is significant and convert the laparoscopic procedure unnecessarily. When bleeding occurs, all known techniques to achieve haemostasis are used as in conventional surgery, e.g. bipolar coagulation, compression of bleeding, ligature with Roeder loop, Endo suture or Endo coagulation.

In the early stages, obesity, adhesions, abnormal positions, abscesses or perforations forced us to convert to open surgery; however, with increased experience we no longer consider these as indications for conversion. Problems relating to operating technique which are caused by abnormal anatomy can easily be solved by changing the position of the patient. Abscesses can be treated with placement of a drain. Adhesions are divided with microsurgical instruments.

Stump Invagination

Since the beginning of this century there has been controversy as to whether to invert the appendix stump or not.

Engström and Fenyö [26] showed in a prospective, randomized study that simple ligature of the stump is a safe method. The wound infection rate did not increase in comparison with stump invagination with a purse string suture following Z suture. Of 374 patients with stump invagination 8.8% suffered from wound infection, as opposed to 8.3% of 361 patients without stump invagination.

As far as umbilical wound infections are concerned, preoperative cleaning and disinfection, for example by inserting an iodine swab 24 h before the procedure, has reduced the infection rate drastically. Moreover, immediately before the incision is made, further disinfection of the umbilicus is performed.

It remains to be established whether the abovementioned extraction technique, which ensures that the appendix does not touch the abdominal walls, is responsible for the low infection rate of the stab incisions in the lower abdomen.

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16 Laparoscopic Cholecystectomy

J. PÉRISSAT

Introduction

Cholesterol gallstones form in the gallbladder. Curative treatment must therefore consist in removal of the stones and preventing their recurrence. Until now the best form of treatment has been cholecystectomy or ablation of the gallbladder. This is well established operation since the first published intervention dates back to 15 July 1882 and was performed in Berlin by Langenbuch. Although much criticized at the beginning since it was often accompanied by complications such as bleeding and biliary fistula, and also since it went against the dogma of keeping the gallbladder in place to ensure the physiological equilibrium of the organism, cholecystectomy has acquired an excellent reputation over the years. Thanks to more accurate anatomical knowledge of the respective positions of the common bile duct (CBD), the hepatic artery, and the cystic artery(ies) (doctoral thesis by Calot, Paris 1890 in [1]), bleeding and biliary leakage have progressively disappeared from the statistics. In the early 1990s it is still possible to say that cholecystectomy is the "gold standard" intervention for treating gallstones [2]. When all clinical forms are considered, mortality is between 0.1 % and 0.5 %, and morbidity between 3 % and 9 %. However, in higher-risk groups such as elderly patients (over 70) or those with infectious complications, the rates for mortality and morbidity from this operation rise three- to sixfold. Finally, among the complications, 2 %–5 % are associated with the laparotomy which is the path of access to the gallbladder. Establishing an operative technique which abolished the need for laparotomy had to lead to improved results.

With this in mind, and following the example set by gynaecological surgeons, a number of pioneers had the idea of applying the techniques of laparoscopic surgery to cholecystectomy. Mouret in Lyon, France, who is both a general and gynaecological surgeon, performed the first laparoscopic cholecystectomy (LC) in March 1987 [3]. Dubois in Paris, who for a long time had been adept in cholecystectomy by minilaparotomy, progressively replaced this approach with the laparoscopic approach from February 1988 [4]. As for myself in Bordeaux, having developed a technique for laparoscopic cholecystolithotomy, I began to finish this intervention with cholecystectomy in November 1988. At the same time the technique was developing in the United States. In June 1988 at Marietta, Georgia, McKerman and Saye performed the first LC with a laser to dissect the gallbladder. This technique developed rapidly under the stimulus provided by Reddick in Nashville, Tennessee, from October 1988 [5]. Until then, clinicians had been acquainted with these techniques on a purely confidential basis. The news really got around in April 1989 during the Congress of the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) in Louisville, Kentucky. There I presented a video film of my operative technique associating intracorporeal lithotripsy and cholecystectomy. The starter's pistol had sounded. Thanks to the dynamism of several American groups such as those headed by Reddick, Berci in Los Angeles [6], Zucker in Baltimore [7], and Europeans such as Cuschieri in Dundee [8], Troidl in Cologne, Buess in Tübingen and Testas in Paris, and, with the aid of leading manufacturers of endoscopic equipment, minicameras, and instruments, LC has really taken off. It has been on everybody's tongue, the subject of numerous scientific communications and presentations at the Annual Congress of the American College of Surgeons, in San Francisco, October 1990. It has become the hallmark of the first confirmed success of the new surgery known as "minimal access" or "minimally invasive."

Indications and Patient Selection

In less than 2 years, LC has moved from being an intervention suitable only in well-selected cases to a routine procedure for most patients with symptomatic gallstone disease. Our team was one of the first to explore this untrodden ground and we have carefully moved forward step by step, applying very strict selection criteria for the first patients to whom this entirely new treatment was proposed [9, 10]. Moreover, any team adopting this technique should do likewise; in this way, they will not cause their patients to run any risk. Our decision-making scheme was as shown in Table 16.1. Our contraindications in the first 100 patients were as follows:

- General contraindications: increased cardiac risk, respiratory insufficiency
- Local contraindications: acute or subacute/chronic cholecystitis with walls greater than 4 mm thick on ultra sonography
- Associated asymptomatic CBD calculi
- Previous abdominal surgical intervention

The subsequent, follow-up and experience have led us to the present stage where we now operate on all patients with symptomatic gallstones by the laparoscopic approach. The only contraindications for us are the presence of unstable cardiac states, as our anaesthetists fear haemodynamic disturbances due to the creation of a pneumoperitoneum. Previous surgical interventions in the supracolic compartment, in particular gastrectomies and previous hepatobiliary or pancreatic interventions, are also contraindications. In other circumstances, contraindications associated with the local state of the lesions, such as gangrenous cholecystitis, appear during laparoscopy. The forceps on the wall made friable by the gangrene may often cause tearing with escape of stones and extravasation of the septic contents into the peritoneal cavity. This normally requires conversion into an open procedure. One of the main advantages of this laparoscopic technique is that it can, in the hands of a biliary surgeon, be converted whenever required into open surgery. Therefore, the less demanding the preoperative selection, the greater the rate of conversion into laparotomy. However, with experience, the trained surgeon averages a conversion rate of 4%–6%.

Any associated CBD stone is assessed in clinical terms. If it is asymptomatic or discovered during preoperative work-up, it is first removed by endoscopic sphincterotomy, with LC being performed the following day, after ensuring that the serum amylase level is not elevated. If the CBD stone is discovered during LC, one should attempt to extract it via the cystic duct. If this is not possible, a temporary transcystic biliary drain should be inserted after cholecystectomy, and ablation of the CBD stone by endoscopic sphincterotomy should be put off until the day after or a subsequent day. However, if the CBD stone is symptomatic (jaundice, cholangitis), it must be treated first postponing LC until relief of jaundice is obtained.

Table 16.1. Decision-making scheme in the presence of gallstones

Asymptomatic gallstones:	No treatment
Biliary colic of low frequency and intensity	medical bile acid treatment plus extracorporeal shockwaves
Biliary colic, both frequent and severe:	Laparoscopic cholecystectomy
Acute cholecystitis and cholecystitis giving rise to numerous acute attacks which have been treated conservatively	Traditional open surgery

Preoperative Preparation

Informed Consent

All patients for LC must be informed of the various steps of the intervention: insufflation to create a pneumoperitoneum; the various instrument insertion points on the abdominal wall; the dissection of the gallbladder and its extraction, with or without intracorporeal lithotripsy. The normal procedure is described: getting up, light refreshment (drinks), ambulation the day after the operation, possible right scapular pain for 12–24 h. We keep patients for at least 1 night postoperatively, and if they live far from the laparoscopy centre and their family doctor is not familiar with patient monitoring, we keep them for 2 nights. We also inform them of the occasional need to convert from laparoscopy to laparotomy; we give the reasons for such conversion, be they difficulties of haemostasis or of dissection of the gallbladder. We underline the fact that the percentage of these conversions varies from 5%–30% in accordance with the degree of advancement of the disease and the severity of infection, of the gallbladder during the intervention. We then explain what the patient will experience after laparoscopic surgery which required conversion: a longer postoperative period, even as much as a week, and the parietal consequences of laparotomy (scarring of the abdominal wall, possible incisional hernia). Finally, we tell them about the possible postoperative complications of LC, i.e., secondary bleeding or the appearance of biliary collections. The signs of the latter include the occurrence of unusually severe persistent postoperative pain, fever, and mild icterus. Such signs may appear from day 2 to the third postoperative week. Our patients are told that if they experience any abnormal symptom (catching their breath, tiredness, facial pallor, blood in stools, fever, hypochondrial pain, jaundice), they should contact their family doctor in order to be quickly readmitted to the laparoscopy centre.

It is essential that family doctors who take over postoperative care be well informed. In this way, the duration of postoperative hospitalization is reduced to a minimum, without risk for the patient.

Finally, each patient is reviewed as an outpatient 1 month after intervention, after undergoing a number of check-up tests performed by his doctor.

Preoperative Work-Up

Preoperative work-up depends on the circumstances in which the patient is admitted for LC. If elective surgery is contemplated preoperative work-up is performed on an out-patient basis under the family doctor's direction. It includes ultrasonography of the liver and bile ducts, with particular emphasis on the CBD to detect any asymptomatic stones. Included also are blood data concerning haemostasis and liver function. We insist on measurement of alkaline phosphatase and gamma-GT to screen for any CBD stone. Systematic work-up includes plain films of the thorax and abdomen and an ECG.

If patients have symptoms of acute cholecystitis, we prefer to admit them immediately. Preoperative work-up is performed in the hospital, in the same way as described above, and includes blood cultures if the infectious symptoms are severe.

Anaesthesia[1]

General Principles

Any endoscopic operation requiring distension of the abdominal cavity by an artificial pneumoperitoneum has haemodynamic and ventilatory repercussions [11].

In haemodynamic terms and according to whether insufflation is with CO_2, N_2O, or air, it causes pressure variations, especially hypotension, sometimes preceded by cardiac dysrhythmias possibly leading to cardiac arrest. Several mechanisms are involved: a circulatory disturbance due to intra-abdominal pressure, the patient's position, a vasovagal reflex in response to a massive abdominal distension or to visceral mobilization. Moreover, ventilatory disturbances favour circulatory failure and disturbances of cardiac rhythm.

[1] This section was written under the direction of E. Gomez, Anesthetist at the laparoscopy centre, CHU, Bordeaux.

In ventilatory terms, there is always a hypercapnia associated with increased hypoxia in chronic smokers and patients with chronic bronchitis. This hypercapnia is often moderate if the patient is under controlled ventilation. Apart from purely anaesthetic reasons, the causes of this ventilatory impact are: diffusion of CO_2 absorbed by the peritoneum; pressure from the pneumoperitoneum and the patient's position, causing the diaphragm to rise up with changes in the ventilation/perfusion ratio, hence a shunt effect or even a relative alveolar hypoventilation.

Patient Selection

In view of all these potential dangers, we select candidates for LC by excluding those who suffer from coronary cardiac failure, rhythmic disturbances, *controlled* arterial hypertension or moderate chronic respiratory failure, and even pathological obesity. Selection criteria are based on the patient's clinical data. Complementary tests include standard preoperative work-up (blood group, coagulation factors, blood electrolytes, leucocyte count), plus an ECG, pulmonary radiography, and sometimes cardiac ultrasonography. Generally, we do not perform laparoscopic surgery on patients who are ASA class III. For all these reasons, prevention of complications is based on general anaesthesia with intraoperative artificial ventilation, premedication comprising a parasympathicolytic, cardiovascular monitoring, and the need for slow insufflation of the peritoneal cavity with CO_2, without exceeding a pressure of 20–25 cm water.

Anaesthetic Protocol

Half an hour before anaesthesia, premedication is administered combining an anxiolytic (diazepam 10–15 mg) with a parasympathicolytic (atropine sulphate 0.75–1 mg). With the patient lying down, a peripheral venous line is established and connected to a colloid infusion of the gelatine type (500 ml) in order to control the hypotensive effects of anaesthetic medication. Pressure is monitored (scope, pulsometer). Urinary and gastric probes are inserted after anaesthetic induction, this is to make the intra-abdominal operative steps safe. Moreover, hourly urine output allows monitoring of the anaesthesia and of subsequent intraoperative intensive care.

We perform neuroleptanalgesia with induction narcosis preceded by test doses of neuroleptics and opiates. The following medication is used:

- Narcotic: propofol 2 mg/kg body weight on induction
- Neuroleptic: droperidol 10–15 mg during the intervention, the dose being administered before introduction of the first intra-abdominal trocar
- Analgesic: fentanyl 10 μg/kg body weight for the initial dose, with eventual increments on the basis of 100 μg every 20 min
- Curariform: vecuronium bromide 0.05 mg/kg, the 30-min action of which requires repeat doses of 0.025 mg/kg body weight. Induction is performed along with heavy denitrogenation followed by local anaesthesia of the pharyngeal wall to enable orotracheal intubation. Curarization is performed only when the pneumoperitoneal puncture needle is in place in order to prevent any transfixing of a deep organ due to muscular relaxation.

Once the auscultatory symmetry has been checked, the patient is linked to the volumetric respirator at a stable frequency of 130 ml/kg, body weight, 16 cycles/mn. The mixture used is NO_2/O_2 equimolecularly; the NO_2 is immediately stopped if there is any suspicion of gaseous embolism. Definitive adjustment of the respirator is made in accordance with the colour of the patient, and with the results of blood gas analysis. Definitive fixation of the endotracheal intubation tube is done only after the pneumoperitoneum has been established since during insufflation diaphragmatic ascension may result in selective bronchial intubation.

Apart from specific cases of established infection, allergy, or an added infection, we administer prophylactic antibiotics at the start of induction. This consists of piperacillin 200 mg/kg body weight which is repeated for up to 24 h.

Postanaesthetic Monitoring

After the intervention, the patient is transferred to the recovery room where cardiorespiratory monitoring continues (scope, blood pressure, ventilation, and temperature). Observations include checking the vascular access lines, the operative region (drainage, blood or liquid loss), and hourly urine output. The patient is extubated according to the classical criteria (respiratory rate, amplitude, symmetry, heart rate, blood pressure, neurological state). The nasogastric tube is then withdrawn, as is the urinary catheter unless further monitoring is required. The patient is then taken back to the ward. The venous line is maintained in order to continue fluid and electrolyte therapy. The norm is 50 ml kg – 24 h – with a supply of 50 g carbohydrate, 4 g NaCl and 2 g KCl. Intravenous antibiotic treatment is continued for 24 h.

Positioning of Patient on Operating Table: Preparation of Operative Field

Patient

The patient is placed in the supine position with legs apart and resting on straight leg-holders for support along the whole length of the lower limbs (Figs. 16.1). The table is slightly sloping (10°–15°), the right arm is placed on an arm-support situated at a right angle to the operating table in order to receive intravenous infusion. The left arm is held alongside the patient's body. The lower limbs and the shoulders are strapped so that the table may be inclined at various angles during the intervention: sloping, right or left lateral inclination, or the Trendelenburg position.

Preparation of Operative Field

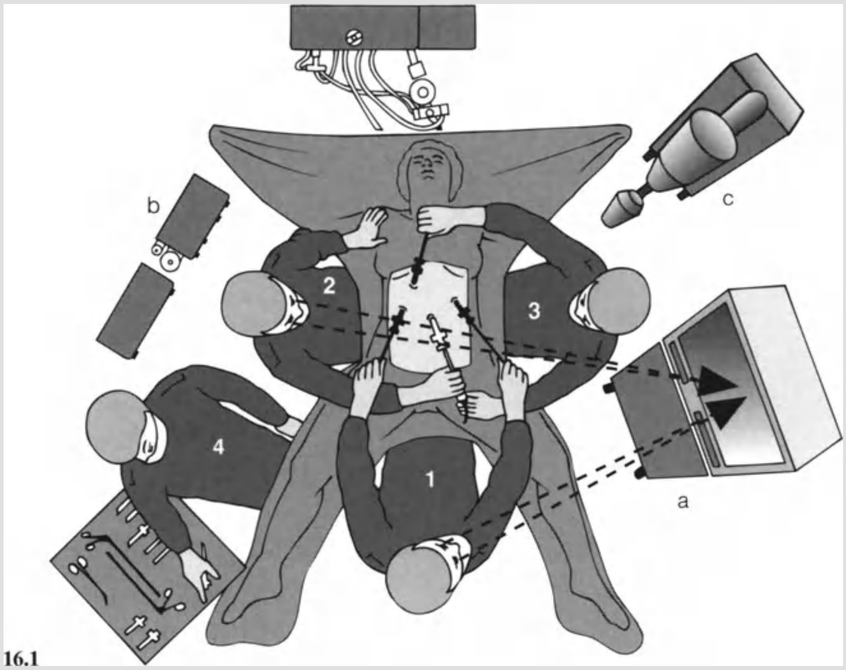
Owing to the head up tilt during most of the intervention, compression stockings are used in the lower limbs. A urinary catheter is inserted. The anterior abdomen, which is prepared the night before the intervention by washing, shaving, and the application of a coloured antiseptic solution, again receives the same solution.

A special sterile operative drape is placed on the skin of the abdomen. It is composed of a tissue paper with an adhesive plastic window revealing mainly the upper part of the abdomen and the periumbilical region. On the right there is a pocket to catch the irrigation liquid which flows abundantly during intracorporeal lithotripsy. This special drape covers most of the operative field. The unprotected parts are covered by traditional sterile drapes.

Layout of Instruments and Staff

Arrangement of Instruments

1. The usual instrument table is situated on the patient's right at the level of the lower limb and includes, from left to right, a tray containing the instruments required for LC: an ultrasonic lithotriptor, a vibrating bar, a series of dilating bougies, plas-



16.1

16.2

Fig. 16.1. Position of the patient and arrangement of the operating room. Patient lying on the operating table, legs apart; *1*, surgeon; *2*, first assistant; *3*, second assistant (optional); *4*, scrub nurse; *a*, insufflator, video system, television screen; *b*, electric cautery, lithotriptor, aspirating and irrigating device; *c*, X-ray machine with television screen

Fig. 16.2. General view of instrument table

tic sheaths (Amplax), forceps for grasing stones (Fig. 16.2). Next, there is the series of instruments including claw forceps with both wide and pointed extremities for insertion into the 5 mm trocars, and jaw-type or "crocodile" forceps for 8-mm and 10-mm trocars, and of two lengths – 50 and 70 cm. Then come the cannulae with various calibre reducers for multiple uses, making it possible to get from 10 mm to 8 mm, 8 mm to 5 mm, and 10 mm to 5 mm. These reducers are positioned at the entry points of their corresponding trocars. Next comes the series of watertight trocars of 5, 8 and 10 mm diameter.

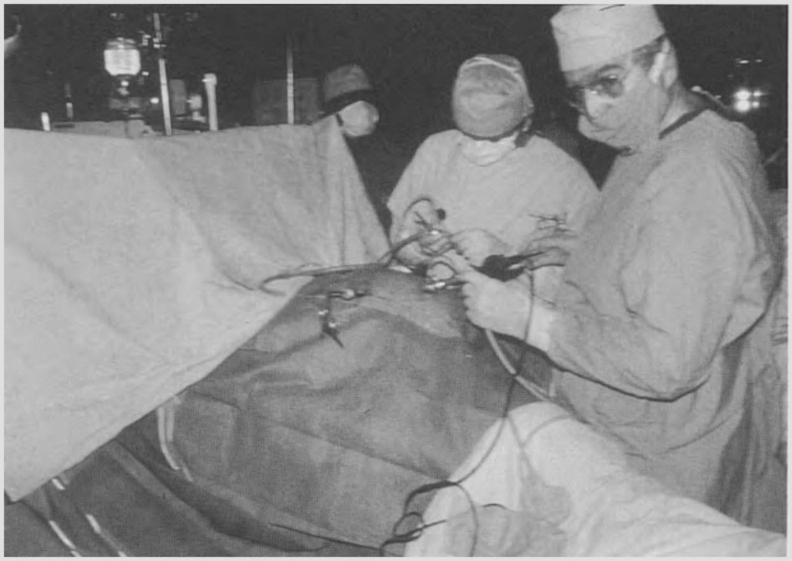


Fig. 16.3. Surgeon standing between the patient's legs

Then there are the hooks for electrocoagulation and dissection, scissors, and possibly the laser handpieces. This is where we place the clip applicators which are inserted into the 8- and 10-mm trocars. Moreover, we make sure we have straight Mirizzi forceps and a long straight vascular clamp, which is useful for recovering any stones that fall into the peritoneal cavity. Then there is a series of Dormia basket probes and a range of Fogarty biliary balloon catheters. Next, there is a special catheter holding forceps for catheterization of the cystic duct during intraoperatory radiography, and a balloon dilator for its dilatation. In reserve there is always a fine fibrescope which is used for transcystic exploration of the CBD. On the right to the table there are some of the usual surgical instruments: Kocher forceps, Kelly forceps, scissors, needle holder, dissecting forceps.

2. The lithotriptor and aspiration/irragation device are situated on the patient's right at the level of the upper limb in order that the optical electrical connections and tubing for irrigation and aspiration lead to the operative field from the patient's right shoulder.
3. The electric cautery, the insufflator, the light source for the laparoscope, and the television monitor are on a movable table on the patient's left at the level of the upper limb; when used, the laser is also placed here. The connecting cables between insufflator and laparoscope, video camera and video cassette recorder, and electric cautery and handpiece come from the patient's left along the lower limb. These sterile connections are fixed onto the operative field with adhesive strips.
4. The X-ray machine for intraoperative radiography is on the patient's left at the level of the shoulder. The device is moved in-field when necessary and fully withdrawn when not in use.

Position of Operating Team

The surgeon is between the patient's legs, either standing or sitting on an adjustable stool (Fig. 16.3). The first assistant is on the patient's right; his/her role is to hold the instruments or the camera. A second assistant may be used although this is not obligatory; he/she is to the left of the patient facing the surgeon. This second optional assistant moves away when the X-ray machine is brought in-field.

A scrub nurse is situated opposite the instrument table between the surgeon and the first assistant. If a laser is used, a team member specialized in handling this device is next to, or replaces, the second assistant.

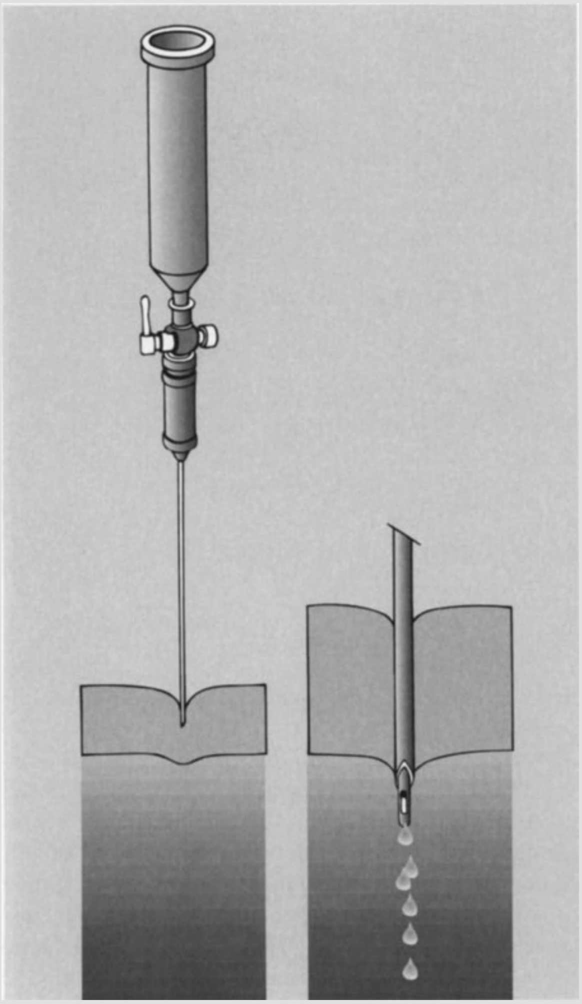


Fig. 16.4. The syringe safety test with saline

Various Steps of the Operation

Abdominal Insufflation

The first step is to establish a pneumoperitoneum with CO_2 insufflation. The peritoneal cavity is punctured either at the umbilicus, if there is no previous operative scar, or in the left hypochondrium along the linea semilunaris point. We use a special disposable needle (Surgineedle – USSC) which has a red cursor on its handle to visualize the passage through the peritoneal layer of the abdominal cavity. There is therefore both a tactile sensation and visual control to indicate entry into the peritoneal cavity. We observe a series of safety rules to check that the insufflation needle is in the right place. The needle is connected to a syringe filled with saline (Fig. 16.4); if installed correctly, the saline simply falls by gravity into the peritoneal cavity. The puncture needle is then connected to the insufflator which is started up at low flow. Correct intraperitoneal gas distribution is percussion controlled. A needle connected to a syringe filled with saline is inserted into the umbilicus. Aspiration causes gas to bubble through the saline. A final safety test is made by directing the insufflation needle towards the umbilicus to see whether there is any contact at this point (Fig. 16.5), which would indicate the existence of an attached bowel loop. If this is so, then another insertion point for the laparoscopic trocar must be chosen. If the needle reveals no obstacle, insufflation is accelerated to a high flow until a pressure of 9–12 mmHg is achieved.

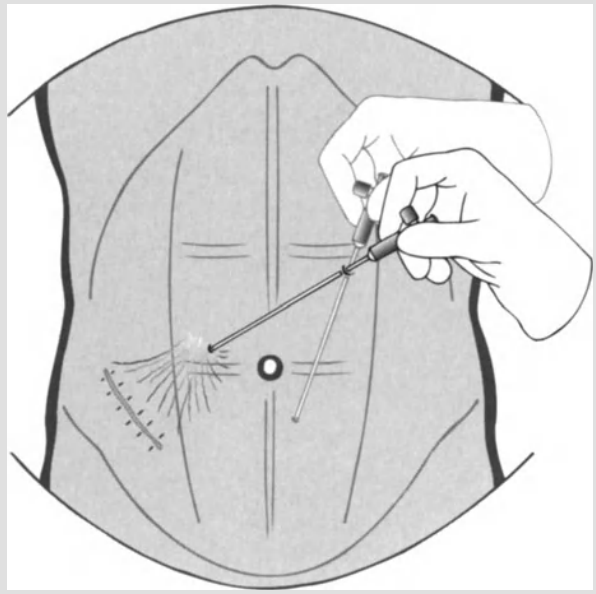


Fig. 16.5. Movement of the needle, after abdominal insufflation, searching for intra-abdominal adhesions

Insertion of Laparoscope

A 10-mm trocar is inserted through the umbilicus (Fig. 16.6). An arched incision of the skin in the upper fold of the umbilicus must be made, and then the cautery is used up to the aponeurosis, which is touched without being penetrated. Care must be taken that the size of the cutaneous incision is no greater than that of the trocar in order to avoid air leakage during intraoperative manipulation. The trocar enters either directly or via a Z trajectory in order to avoid postopera-

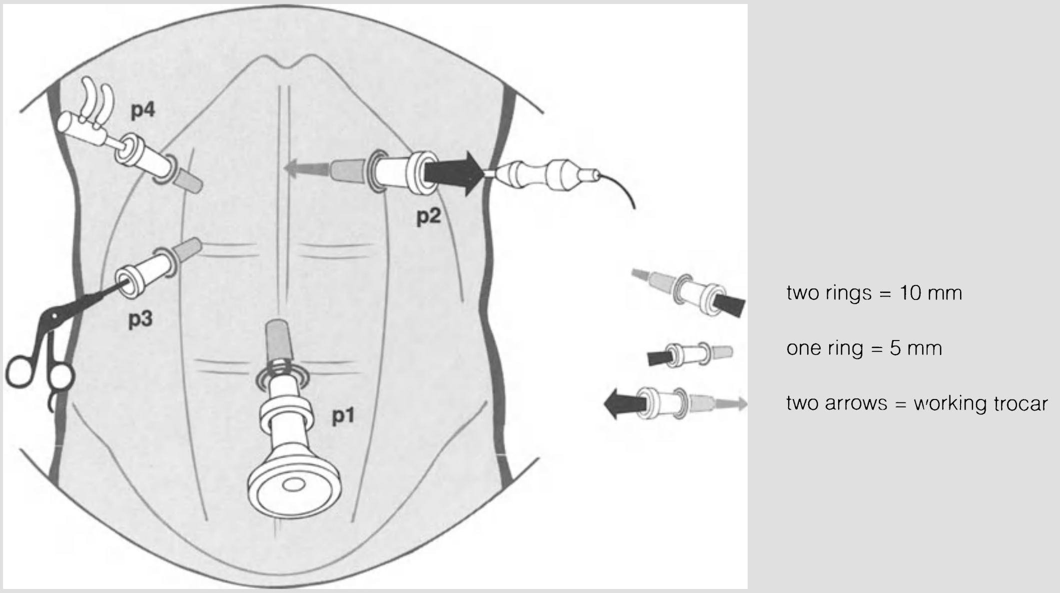


Fig. 16.6. Position of instruments. *p1*, laparoscope, 10-mm port through the umbilicus; *p2*, 8- or 10-mm port for electric cautery, laser, scissors; *p3*, 5-mm port for grasping forceps; *p4*, 5-mm port for aspirating and irrigating device, retractor to lift up the liver

tive parietal dehiscence. Some surgeons prefer to open the skin and aponeurosis with the cautery to make sure there is no subjacent visceral adherence. The trocar is then inserted, and a suture is inserted and tied around the orifice of introduction to ensure that it is hermetically sealed. The direction of penetration is upwards and slightly to the right towards the gallbladder. We use a 10-mm laparoscope which is either forward viewing or 30° forward oblique. A camera is connected to the laparoscope and the intervention proceedes under television monitoring. The peritoneal cavity is inspected, and a specific check made to exclude damage by the insufflation needle.

Instrument Insertion

An 8-mm trocar (port no. 2) replaces the insufflation needle in the left hypochondrium; it enables the introduction of the clip applicator, the dissecting forceps and the laser if this is being used. A second trocar (port no. 4) is inserted into the right hypochondrium two fingerwidths from the costal edge, this allows insertion of the irrigation-aspiration device. It is used to raise the inferior surface of the liver and thus open up the subhepatic space. The gallbladder is visualized at this point.

A third trocar of 5-mm diameter (port no. 3) is inserted into the right hypochondrium, lower than the preceding one. Its position is determined by the operator depressing the anterior abdominal wall by the index of the left hand. The point of insertion is deemed to be the point where the finger shows the shortest distance from the fundus. A forceps is introduced through this trocar and is used to grasp the fundus to draw it downwards and to the right, or on the neck of the gallbladder to draw it to the right and slightly downwards, thus opening up the Calot triangle and revealing all its components: the position of the CBD, the cystic duct, and the cystic artery.

Dissection and Control of Cystic Artery and Duct

The correct position of the grasping forceps opens up the Calot triangle. Through port no. 2, the surgeon inserts the scissors or the dissecting hook onto which the electric cautery cable is connected. The peritoneum of the neck of the gallbladder is opened at its lower part using the convex part of the hook, using a low-intensity electrocoagulating and sectioning current (Fig. 16.7). Once the visceral peritoneum is opened by using coagulation and sectioning sparingly, it becomes possible with small lateral movements parallel to the presumed orientation of the cystic duct to open more widely the visceral peritoneum and begin to dissect the

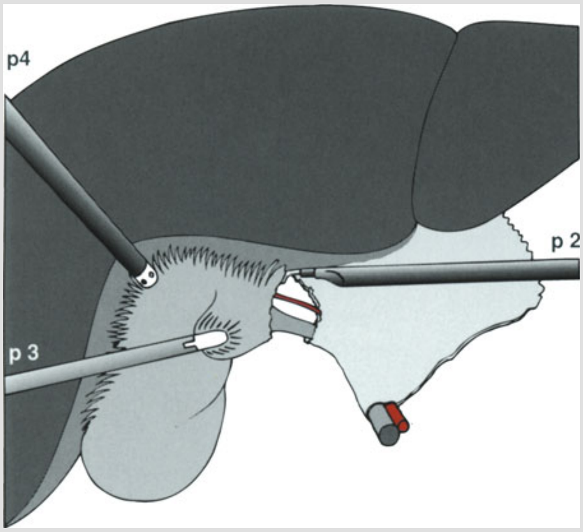


Fig. 16.7. Beginning of dissection of Calot's triangle. *p2*, scissor or hook dissector; *p3*, grasping forceps holding the gallbladder neck and making a traction downwards and to the right; *p4*, retractor lifting up the liver

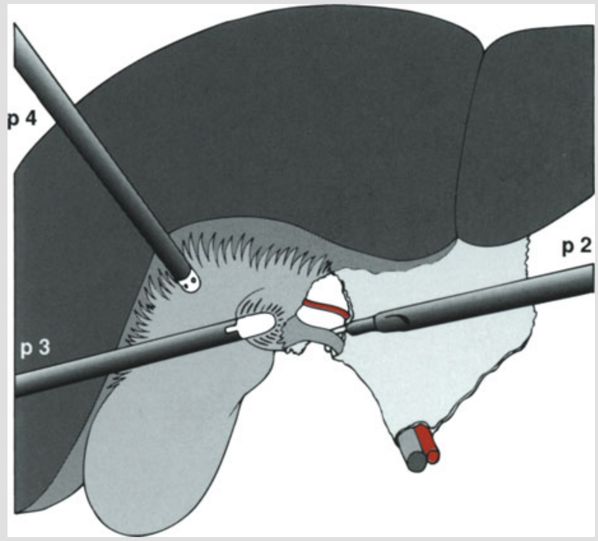


Fig. 16.9. Cystic duct and artery are demonstrated ready for clipping

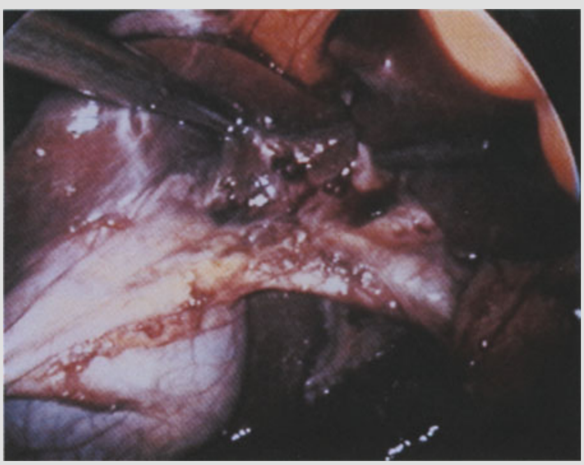


Fig. 16.8. Dissection of the connective tissue surrounding the cystic duct

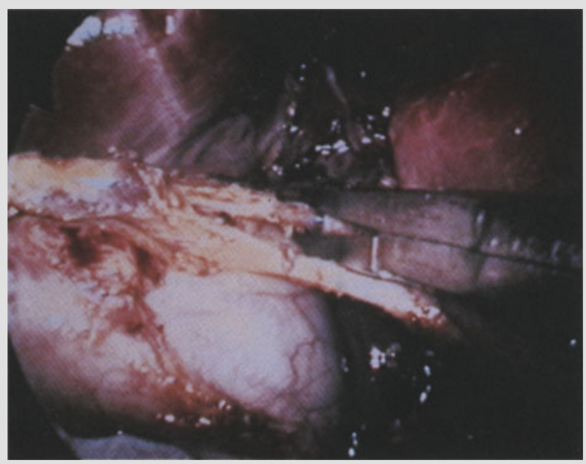


Fig. 16.10. Clip placed on the cystic artery

connective tissue surrounding the cystic duct (Fig. 16.8). This is then progressively freed and clearly identified, since its junction with the CBD must be demonstrated. The cystic duct is secured with a clip on the vesicular side, and the cystic artery is sought above it. Frequently the surgeon comes upon a lymph node, Mascagni's node, on the neck of the gallbladder. Using similar touches of electrocoagulation with the convex part of the hook to open up the visceral part of the peritoneum and lateral dissecting movements, it is possible to clean the connective tissue around the artery and lift it by the concave part of the hook to clearly define its contour (Fig. 16.9). The hook is then withdrawn along the left trocar and is replaced by the clip-applicator allowing two clips (Fig. 16.10) to be placed on the proximal part of the cystic artery and one clip on the distal part (Fig. 16.11). The clip application is withdrawn and replaced by the scissors which are used to divide the cystic artery between the clips (Fig. 16.12).

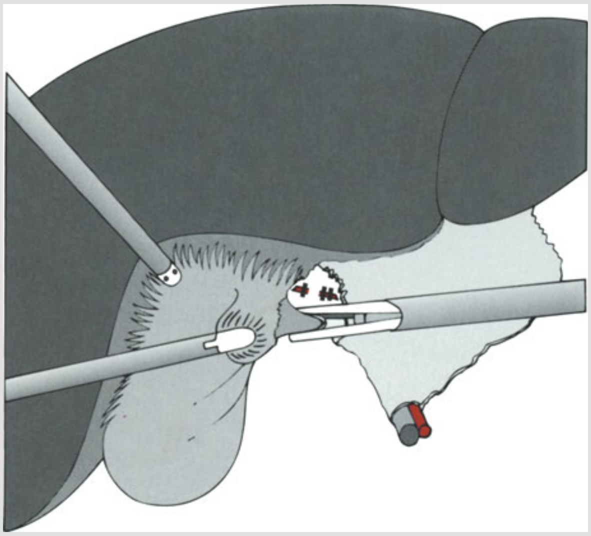


Fig. 16.11. Clipping of the cystic duct close to the gallbladder neck

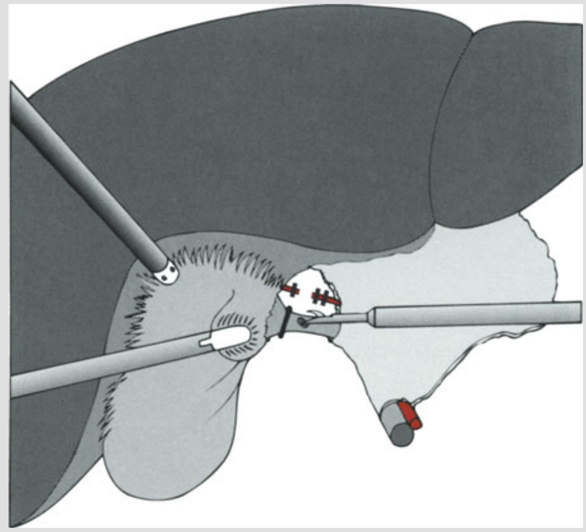


Fig. 16.13. Partial opening of the cystic duct

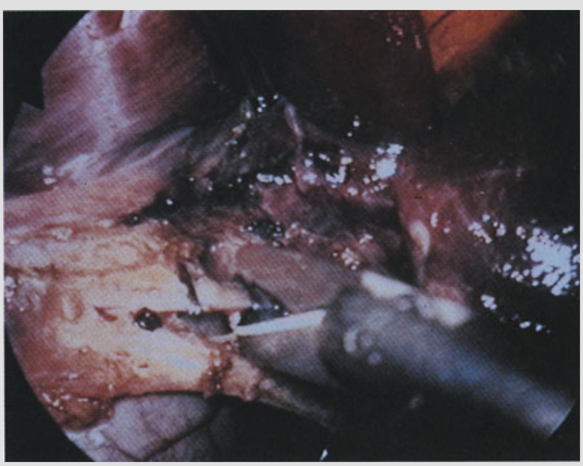


Fig. 16.12. Cystic artery divided between clips

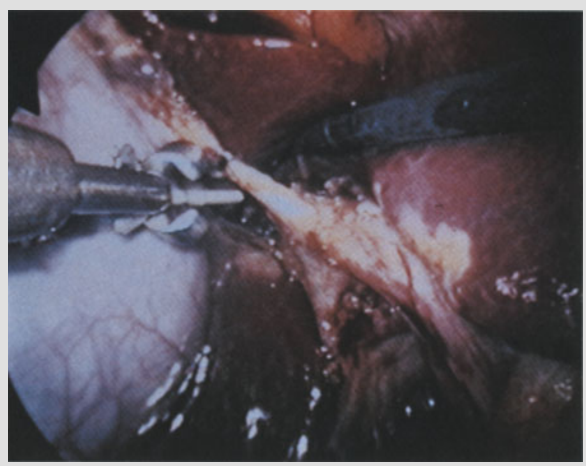


Fig. 16.14. The cholangiographic cannula is prepared

The surgeon now concentrates on the cystic duct. If it is larger than 2 mm and if preoperative work-up has not convincingly demonstrated the absence of a CBD stone, intraoperative cholangiography is performed.

Intraoperative Cholangiography

The cystic duct is opened with the microscissors with care to avoid complete transection (Fig. 16.13). The special cholangiographic cannula with F 4–5 ureteric catheter is inserted through port no. 4. The catheter reaches the lateral opening of the cystic duct. Using the grasping forceps on the neck of the gallbladder, the surgeon must position the cystic duct to enable insertion of the ureteric catheter (Fig. 16.15). The jaws of the special small cholangiographic cannula fix the transcystic catheter to the cystic duct (Fig. 16.16). Initial X-ray screening is used to ascertain concrete positioning of the catheter tip. A few drops of contrast medium are then injected into the latter and if ductal filling is confirmed by image intensification, more contrast is injected slowly. Several films are then taken as the bile duct fills. It is always important to capture the

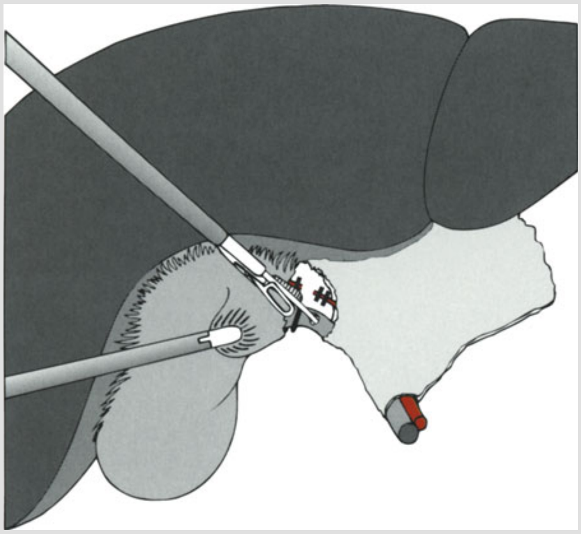
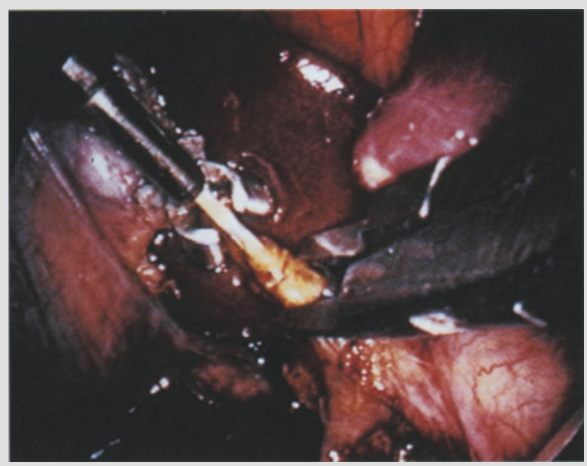


Fig. 16.15. Catheterization of the cystic duct for intraoperative cholangiography

16.17

Fig. 16.16. Catheterization of the cystic duct



16.18

Fig. 16.17. Intraoperative cholangiogram

Fig. 16.18. The catheter is withdrawn and a clip placed onto the cystic duct

moment when the contrast starts to empty into the duodenum (Fig. 16.17). If cholangiography does not reveal any CBD stone, the catheter is withdrawn. The clip applicator is inserted into trocar no. 1 and is used to clip the cystic duct (Fig. 16.18) between its junction with the bile duct and the opening used to insert the catheter. The clip applicator is withdrawn and replaced by scissors for division of the cystic duct.

Dissection of Hepatic Attachments to Gallbladder

Once the cystic duct and artery are clamped and divided, the surgeon moves towards the liver whilst maintaining contact with the neck of the gallbladder and progressively dissects the connective tissue using touches of electrocoagulation (Fig. 16.19, 16.20). The neck of the gallbladder begins to be freed of its hepatic attachments. Dissection must be performed carefully, since the surgeon frequently encounters small accessory cystic arteries in the fat around the neck of the gallbladder. If these arterioles exceed 1 mm in size,

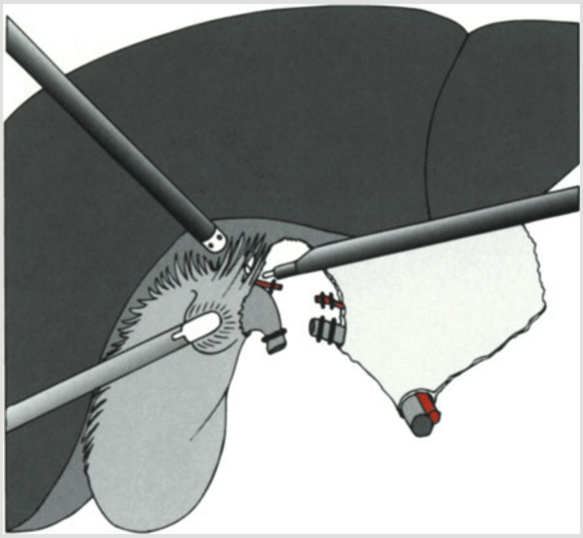


Fig. 16.19. After the cystic duct and artery have been divided with scissors, the hepatic attachments of the gallbladder are sectioned

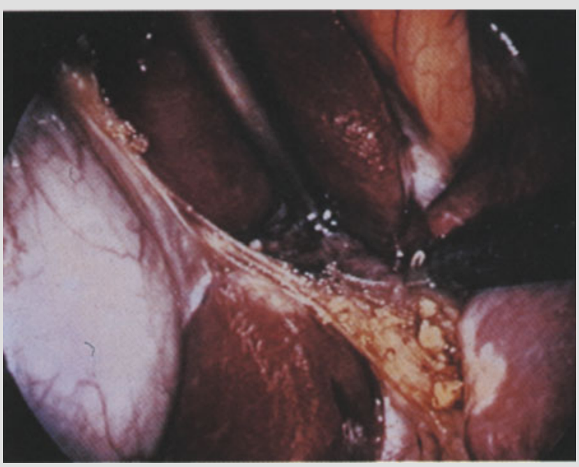


Fig. 16.20. Duct and artery are divided

they are clipped before being sectioned; if smaller, they are electrocoagulated and cut. Division of the gallbladder attachments is performed with scissors or with the dissecting hook electrode. In this way, it is possible, proceeding from the neck of the gallbladder to the fundus, to free all the hepatic attachments while staying close to the gallbladder without opening it.

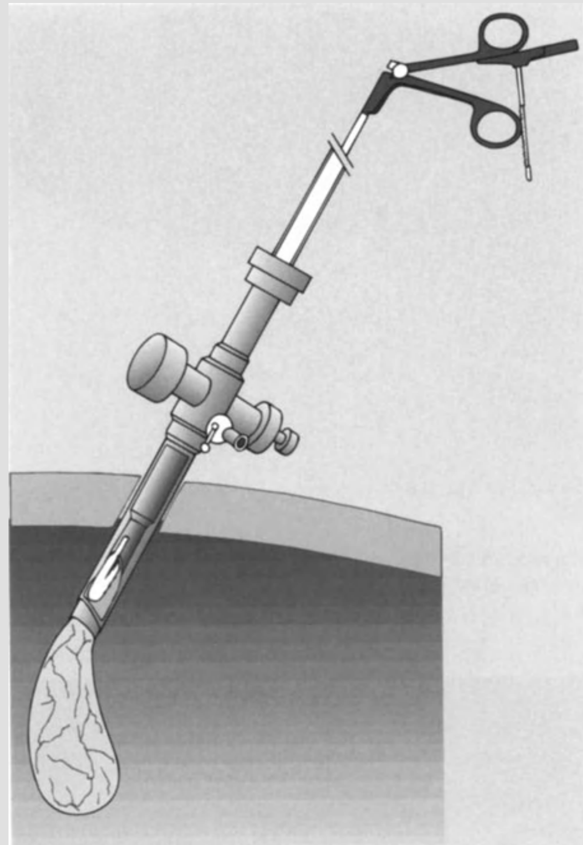


Fig. 16.21. The crocodile forceps grasps the neck of the gallbladder and draws it as far as possible into the cylinder of the trocar

Extraction of Gallbladder

There are several extraction techniques depending on the size of stones and the feasibility of intracorporeal lithotripsy.

Method 1. The crocodile forceps inserted into trocar no. 1 grasps the neck (Fig. 16.21) of the gallbladder and draws it as far as possible into the cannula while laparoscopic viewing is performed through the umbilicus (Fig. 16.22). The forceps should be brought out en bloc with the trocar whose extremity contains the neck of the gallbladder (Fig. 16.23, 16.24). Once this is visible on the skin, it is grasped by three (Fig. 16.24) Kocher forceps arranged as a crown. The neck is opened, and the aspirator is inserted into the gallbladder to evacuate the bile. The part of the gallbladder still in the abdomen decreases in volume and may easily be passed through the 8-mm orifice made for inserting the trocar. The gallbladder is gradually drawn to-

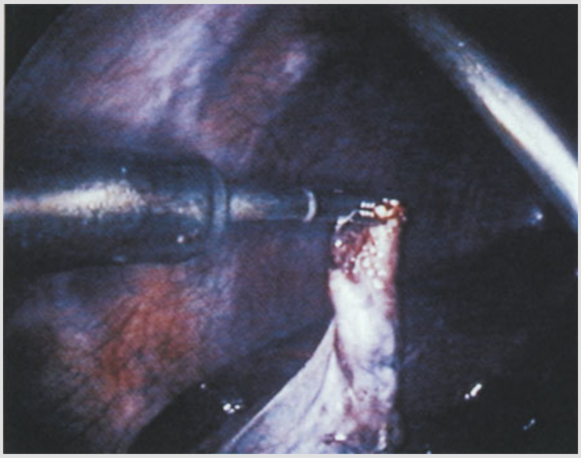


Fig. 16.22. The crocodile forceps has grasped the neck of the gallbladder

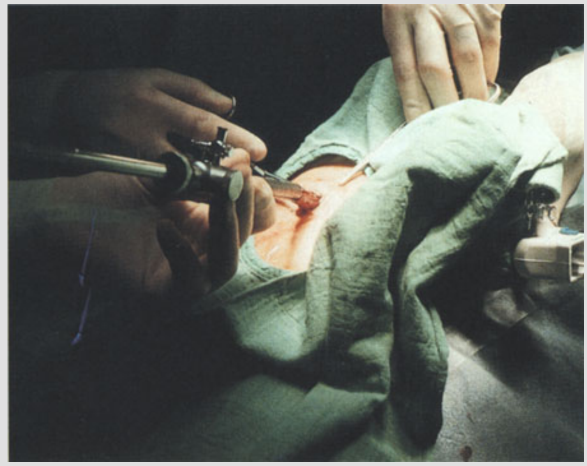


Fig. 16.24. Extraction of the gallbladder

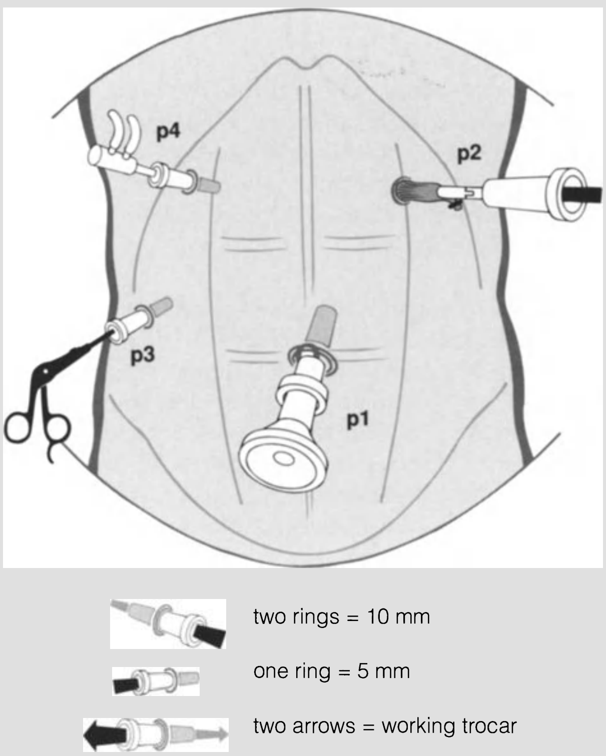


Fig. 16.23. Extraction of the gallbladder through the left port

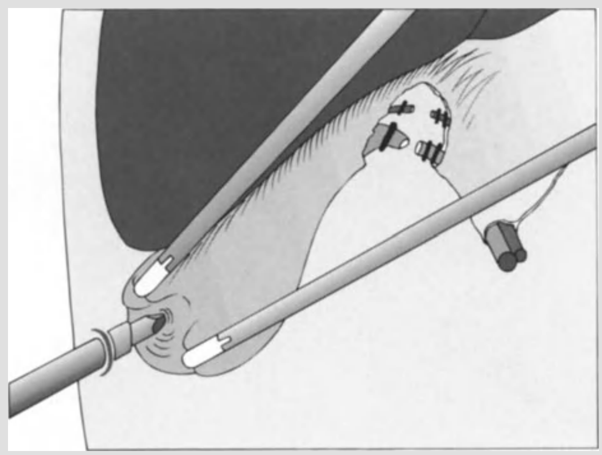


Fig. 16.25. The fundus of the gallbladder is held by two grasping forceps and perforated by the trocar of port no. 3

wards the exterior under visual laparoscopic control through the umbilicus.

Method 2. If the stones are large (>10 mm) and numerous, it is impossible to bring the gallbladder through the 8-mm orifice of the left hypochondrium. Internal lithotripsy is therefore performed after clamping the cystic duct and artery, before sectioning the hepatic attachments to the gallbladder. The fundus is grasped by two forceps inserted into ports nos. 2 and 4, respectively. Port no. 3 is again equipped with its chuck and inserted directly into the fundus (Figs. 16.25, 16.26). The chuck is then withdrawn and replaced by a series of dilatation bougies to create a 27 French orifice (Fig. 16.27). The last two bougies are withdrawn and replaced by a plastic sheath (Amplax). This ensures a hermetic seal around the point of penetration into the gallbladder. The cholecystoscope is then inserted into the plastic sheath; it has a lateral viewer and a central operating channel. It is also

Fig. 16.26. Introduction of trocar no. 3 into the gallbladder fundus to perform intracorporeal lithotripsy

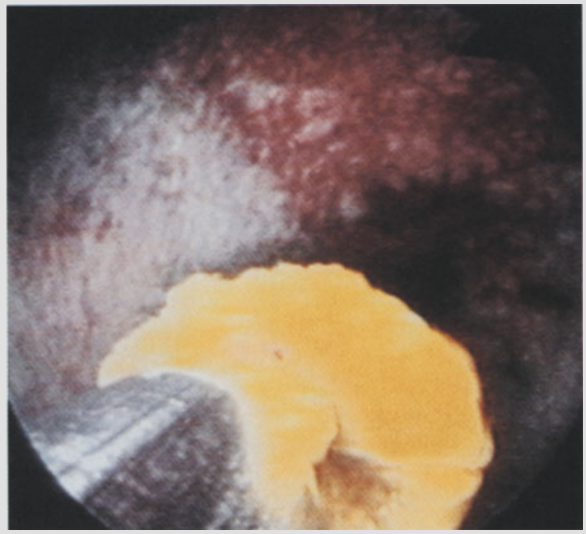


Fig. 16.28. Ultrasonic stone fragmentation inside gallbladder

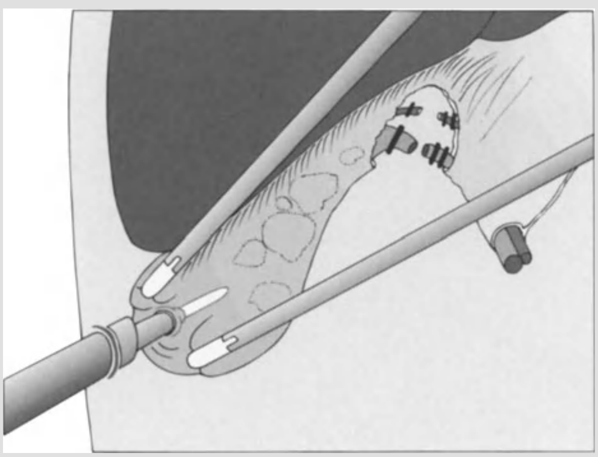
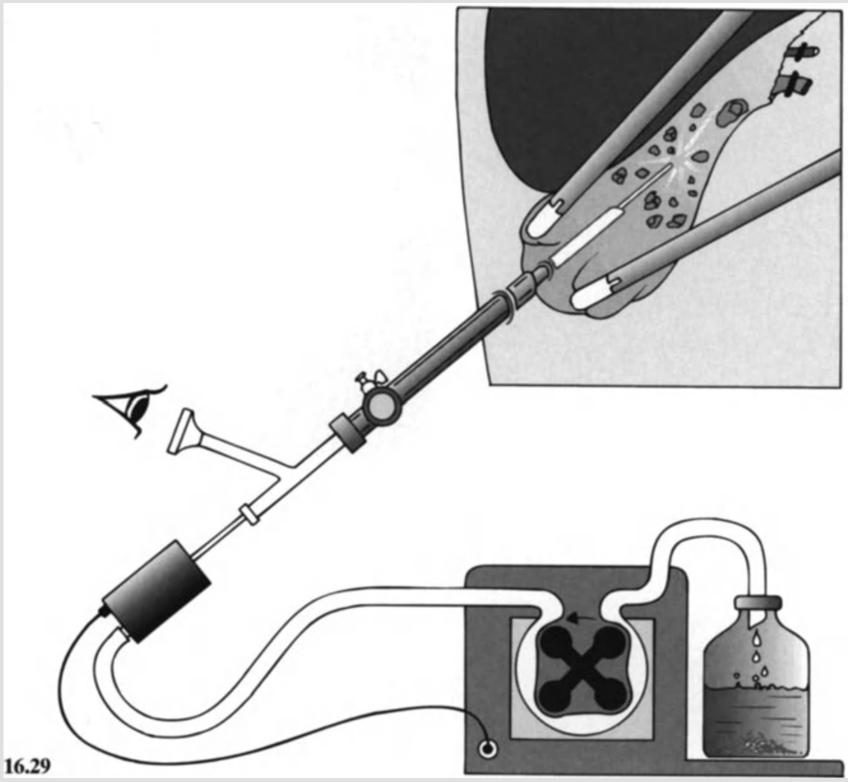


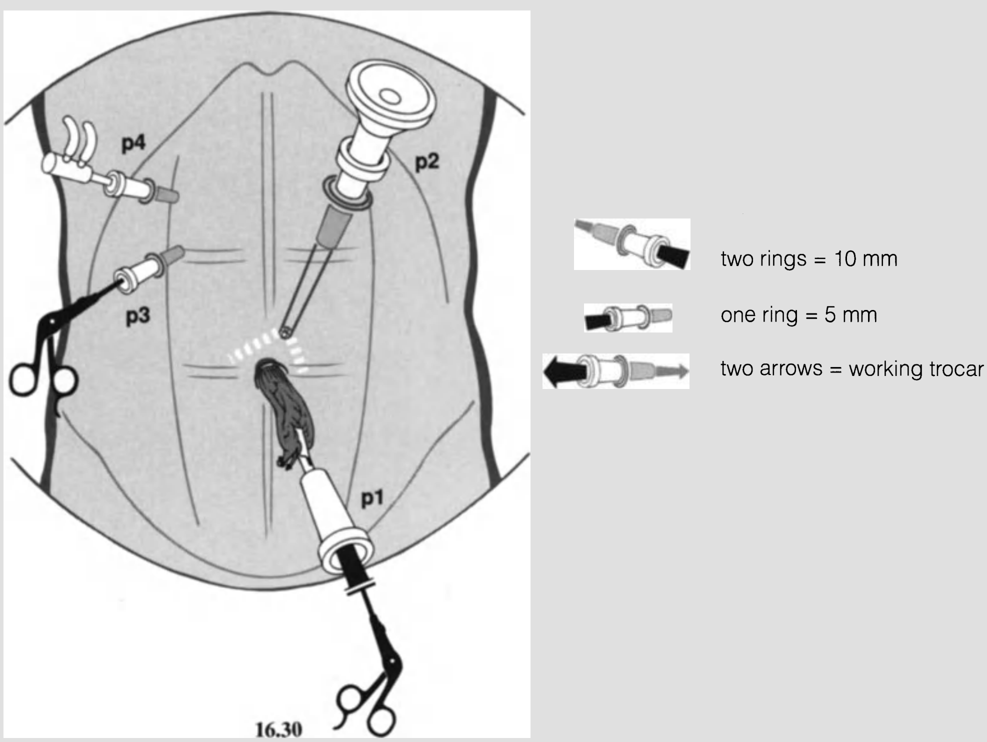
Fig. 16.27. Progressive dilatation by metallic bougies of the orifice in the fundus of gallbladder securing a hermetic seal

equipped with a sheath allowing continuous irrigation and washing for perfect vision of the inside of the gallbladder. The bar of the ultrasound lithotriptor is inserted into the operating channel of the cholecystoscope. A camera is connected to the latter and the point of the lithotriptor is brought into contact with the stones under visual control (Fig. 16.28). Ultrasonic firing then pulverizes the stones, the debris of which is aspirated across the hollow vibrating bar of the lithotriptor (Fig. 16.29). The stones are destroyed and evacuated progressively. The gallbladder is thus emptied of its stone load. The lithotriptor and the cholecystoscope are then withdrawn. A crocodile forceps is inserted into the plastic sheath, again enabling the neck of the gallbladder to be grasped. The hepatic attachments to the gallbladder are then sectioned as in method 1. Finally, the gallbladder is easily drawn through the plastic sheath by the crocodile forceps and is progressively extracted through the port in the right hypochondrium [12].

Method 3. Large-volume stones require intracorporeal lithotripsy. Since the gallbladder is still in place, this may not be possible for technical reasons such as the presence of a scleroatrophic gallbladder containing no liquid. Likewise, with large impacted stones it is impossible to puncture and penetrate the gallbladder lumen. In these situations, all the hepatic attachments to the gallbladder are divided. As in method 1, extraction is through the largest (10-mm) orifice. For this, the trocar in the left hypochondrium is replaced by a 10-mm trocar. The laparoscope is transferred from the umbilicus. A 10-mm crocodile forceps is inserted into the transumbilical trocar in place of the laparoscope; it enables the neck of the gallbladder to be grasped and drawn progressively into the trocar under the visual control of the laparoscope inserted into the left hypochondrium. After the neck of the gallbladder has been exteriorized (Fig. 16.30), it is opened and the aspirator inserted to evacuate the bile. If there is none and if the large stones cannot be withdrawn, a large Kocher forceps is inserted into the gallbladder to break the stones inside. If this is not possible, an ultrasonic lithotriptor is inserted and intracorporeal lithotripsy performed on the detached gallbladder as it



16.29



16.30

Fig. 16.29. Intracorporeal lithotripsy of gallstones in the in situ gallbladder

Fig. 16.30. Extraction through the umbilicus. The laparoscope has been moved from the navel port to port *no. 2*

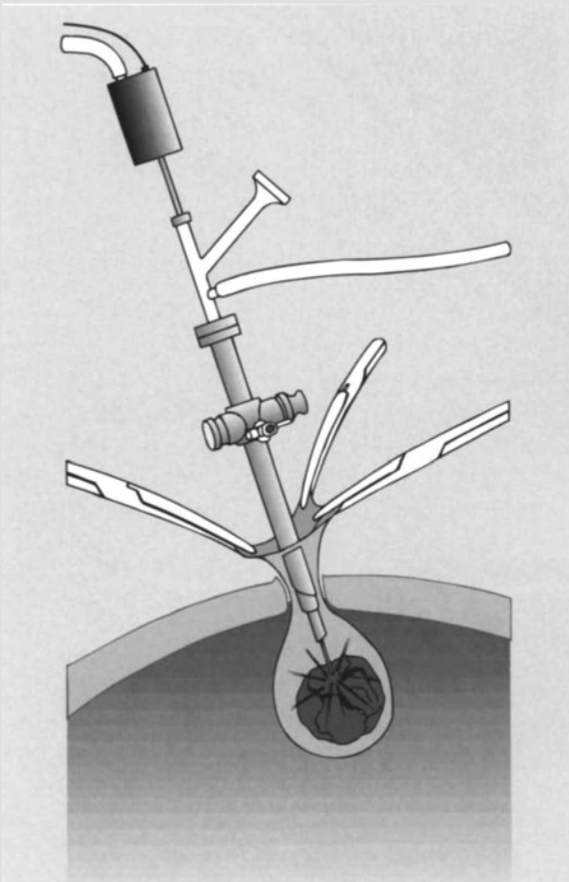
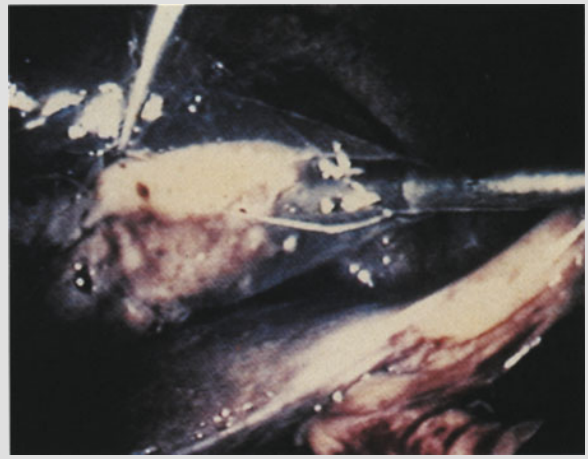


Fig. 16.31. Extraction of big gallstones. Lithotripsy performed on a detached gallbladder hanging from the abdominal wall



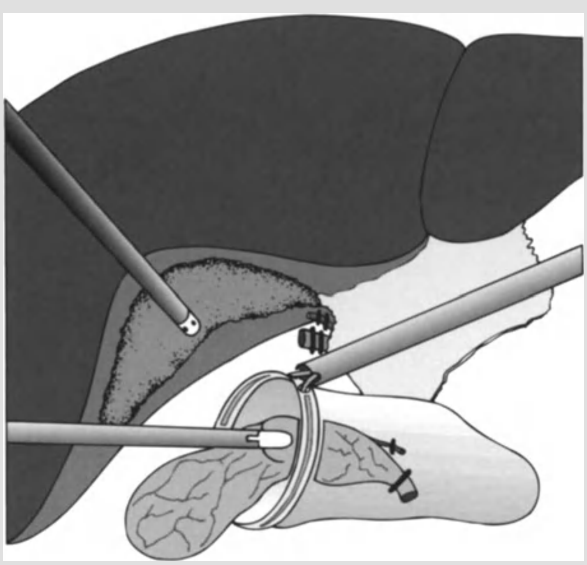


Fig. 16.32. The "extracting bag" technique. The detached gallbladder still full of calculi is put inside a plastic bag

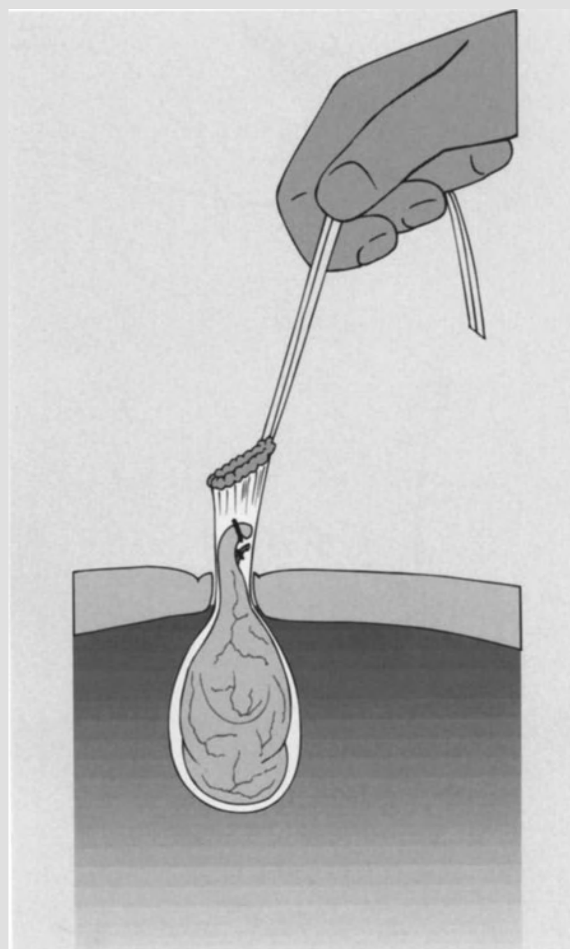


Fig. 16.34. The "extracting bag" technique. The plastic bag containing the gallbladder is extracted through the umbilical orifice. Morcellation of the bag's contents is done to permit the complete withdrawal of the bag

exits through the abdominal wall (Fig. 16.31). These manoeuvres are sometimes difficult and may lead to partial perforation of the internal part gallbladder. Some stones may to fall into the peritoneal cavity and these are sometimes difficult to recover. However, this must be achieved. Once the stones are broken, the general decrease in volume that this causes enables extraction of the gallbladder. When the gallbladder wall seem fragile and its contents are septic, it may be placed in a plastic bag inserted through port no. 2 (Fig. 16.32). The bag is partially withdrawn through the umbilical orifice, and fragmentation of the stones is performed inside the bag until their diameter allows them to be totally evacuated (Figs. 16.33, 16.34). We call this technique the "extracting bag" technique. But if lithotripsy has been to no avail, the decision must be taken to finish by enlarging the wound by extending the aponeurotic incision to deliver the gallbladder. The aponeurotic layer must always be closed by one or two sutures.

Washing and Draining of Peritoneal Cavity

After gallbladder extraction, which always causes a large gas leakage, the pneumoperitoneum is re-established by automatic insufflation. The laparoscope is again inserted into the umbilicus and the grasping forceps are reinserted into the trocar of the left hypochondrium. A grasping forceps is now inserted into the orifice of the right hypochondrium. The hepatic bed is inspected (Fig. 16.35) and the correct positioning of the clips on the cystic artery and duct is checked. Extensive irrigation and aspiration is performed and any clots evacuated. The abdominal cavity is then fully inspected with the patient being progressively turned from the head up tilt to the Trendelenburg position with a lateral tilt to the right to collect as much liquid as possible in the right hypochondrium and in the right subphrenic space. Then several alternating irrigation-aspiration sequences are performed. One must plan for an irrigation volume fo 3–6 l saline at 30 °C until the liquid becomes clear. Subhepatic drainage is used when required; it is recommended when a very infected gallbladder has been removed and when the cystic duct seems so fragile that subsequent clip dislodgement becomes a posibility. The drain is then left in place for 24 h.

Withdrawal of the Instruments and Abdominal Desufflation

The forceps in trocars nos. 3, 4 and 2 are progressively withdrawn. The laparoscope is withdrawn, and the valve of the trocar in the umbilicus is opened to manually evacuate most of the gas in the pneumoperitoneum. The umbilical trocar is then withdrawn, and the patient is positioned horizontally.

Closure of Trocar Insertion Points

Closure of the cutaneous orifices is either by sutures with absorbable material or by Steristrips. The aponeurotic orifices are not closed unless it has proved necessary to enlarge them to extract a large gallbladder full of large stones which could not be broken beforehand.

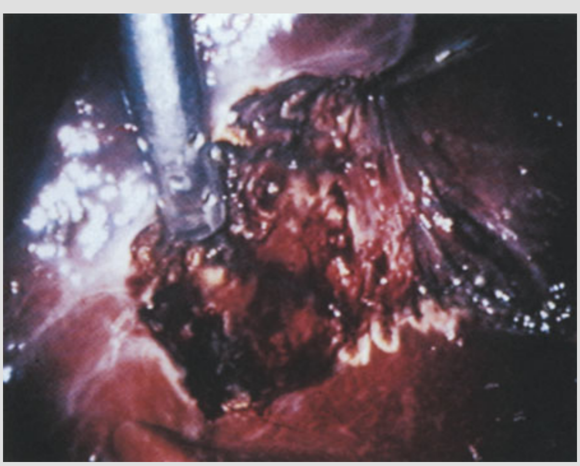


Fig. 16.35. View of hepatic bed after removal of gallbladder

Postoperative Care

The patient remains in the recovery room until return of the protective reflexes. Both the nasogastric tube and urinary catheter are removed. A peripheral venous line is maintained for the first 12 h postoperatively; this also allows the administration, if necessary, of intravenous antispasmodic or antiemetic agents. A complete clinical examination is performed the morning after the intervention. A plain abdominal film is taken. If used, the subhepatic drain is withdrawn if there is no damage, but otherwise it is left in place. The patient is allowed to drink and get up. If no alarming symptoms develop the patient is allowed home on the evening of the day after the intervention, as long as there is adequate medical care at home. Patients who live far from the laparoscopy centre are kept in hospital one more night.

The alarming symptoms which indicate the onset of complications are fever, abdominal pain in the right hypochondrium or throughout the abdomen, the absence of intestinal sounds on auscultation, and vomiting. If such symptoms do occur, hospitalization is prolonged. In about 10% of cases, the patient complains of right scapular pain. This is due to the pneumoperitoneum and should subside within 10 h. In most cases, there are no alarming symptoms and the patient recovers quickly. Return to full activity is usually achieved within 1 week, and the patient allowed to return to work and to engage in sporting activities 10 days after the intervention.

The patient is examined fully again as an out-patient 1 month after the intervention. The family doctor prescribes ultrasonography of the liver and bile ducts, a plain film of the abdomen, and assays of alkaline phosphatase and gamma-GT. The patient attends the out-patient final with the results. A complete check is performed 1 year later.

Technical Variants

Disease and a Normal Bile Duct

The technique described above is the one we developed at the end of 1988 and the beginning of 1989 and which has subsequently undergone only minor changes. It is largely similar, apart from the technique for intracorporeal lithotripsy, to those performed by Dubois and Mouret, the first pioneers, and to those adopted by most biliary surgeons in Europe (Cushieri, Great Britain; Troidl, Germany [13]; Gigot, Belgium; Vincent, Spain, etc.). However, alongside these European developments, in June 1988 McKernan and Saye in Marietta, Georgia, performed LC with a laser. The same technique has been used and encouraged by Reddick in Nashville, Tennessee, from October 1988 [14]. The three main points which differentiate the American from the French technique are:

- Position of patient on the table and the position of the operating team and technical equipment used
- Instrument insertion points in the abdominal cavity
- Use of lasers for dissection and haemostasis

Position of Patient, Operating Team and Instruments

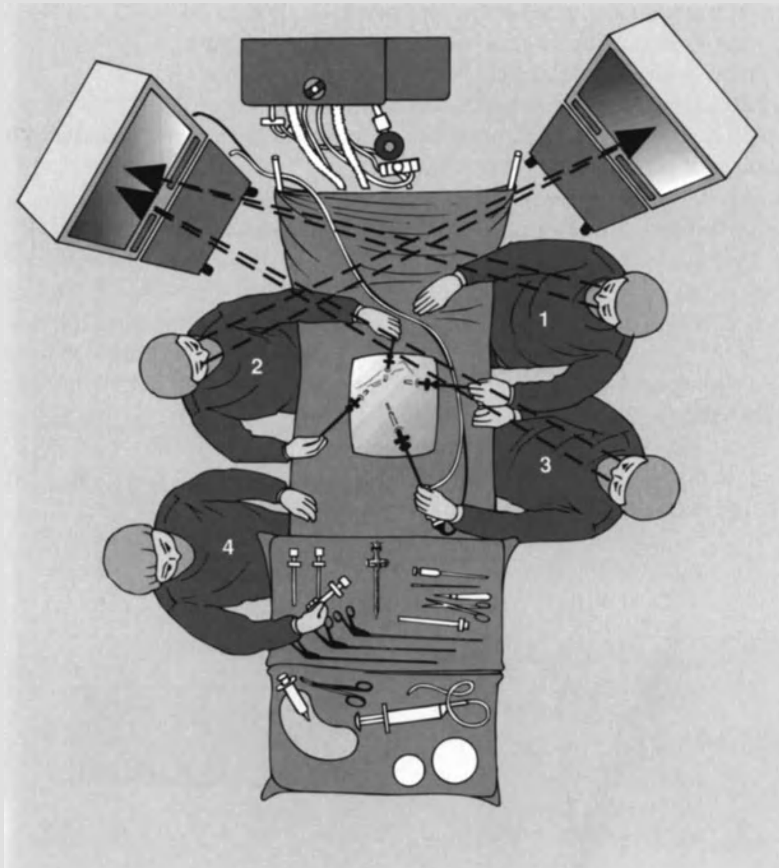
The patient is placed in the supine position with a head up tilt (Fig. 16.36). The surgeon is on the patient's left, as is the second assistant in charge of the camera. The first assistant stands opposite the surgeon, as does the scrub nurse. A further assistant is responsible for operating the laser. The main television screen is opposite the surgeon on the patient's right. A second screen is on the left so that the first assistant may also follow the operative procedure. The various devices are set around the team, normally on the patient's left and behind the surgeon. The mobile X-ray camera is on the patient's right next to the leg; when required, it is moved into the operating field.

Instrument Insertion Points

All insertion points are to the right of the midline and vary according to patient morphology (Fig. 16.37). Port no. 2 is used to insert the dissecting forceps, the electric cautery or laser, and scissors and clip applicator. Port no. 4 is used for traction upwards and laterally of the neck of the gallbladder. Port no. 3, which is the lowest, enables the insertion of a grasping forceps on the fundus which is drawn upwards, thereby raising the anterior face of the liver and freeing the whole subhepatic region. The laparoscope is inserted into the umbilicus. If the Calot triangle is difficult to dissect, a fifth orifice is made between the umbilicus and port no. 2 to facilitate dissection, electrocoagulation, and irrigation of the operating field.

Use of Lasers

The action of lasers on living tissue is well known. The main effect is heating (joule effect) causing coagulation or destruction of tissues by vaporization, according to the wavelength used and mode of application. In view of the necessity of introducing the ray vector through the narrow orifices of laparoscopic trocars, only wavelengths transportable by fibre optics can be used. These are mainly argon and Nd-YAG lasers from the visible green 400–600 nm to the invisible infrared 1064 nm. These lasers have the dual properties of coagulation and vaporization in their continuous emission mode, according to whether one withdraws (defocalization-coagulation) or approaches (focalization-vaporization) the focal point of the ray to the tissue to be treated. The argon between 488–514 nm and an intermediary laser, the "KTP," reinforced by adding the Nd:YAG, are the most frequently used. Their promoters [15] underline the quality of cut and



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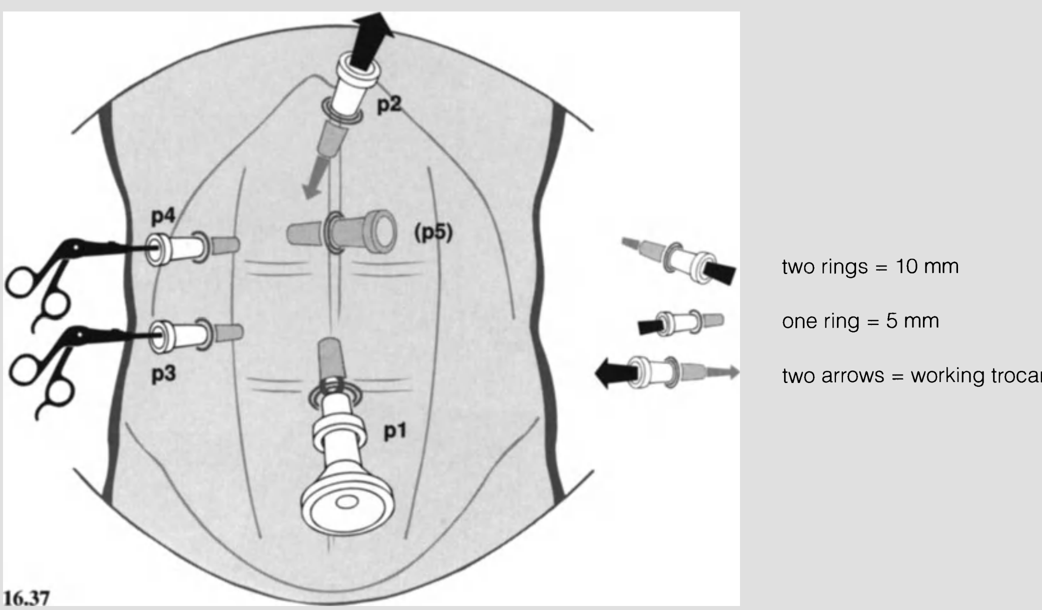


16.37

Fig. 16.36. Position of staff and instruments in the operating room in relation to the patient, when the surgeon stands on the left-hand side of the patient. *1,* surgeon; *2,* first assistant; *3,* second assistant or laser assistant; *4,* scrub nurse

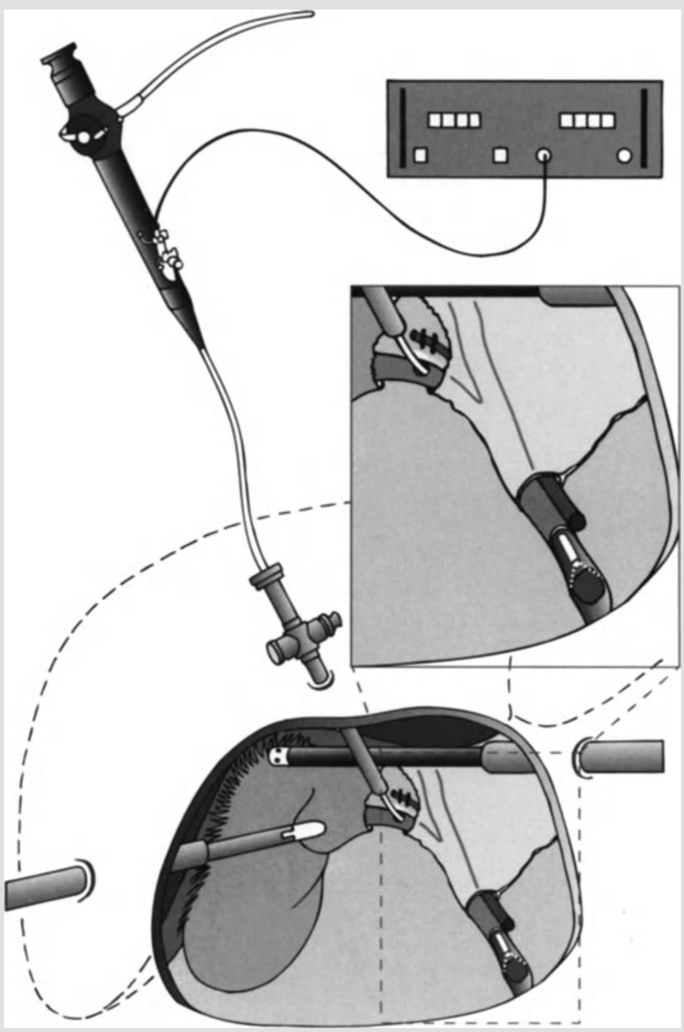
Fig. 16.37. Instrument insertion points in the American technique. *p2,* 10-mm port for dissection; *p3,* 5-mm port for grasping forceps; *p4,* 5-mm port for grasping forceps lifting up the fundus of the gallbladder; *p5,* 5-mm port (optional)

coagulation obtained owing to their precision and the absence of neighbouring heat propagation, whereas the latter is well known with electrosurgical techniques. The use of lasers in laparoscopic surgery, as in open surgery, implies the same protective measures for the operating team and support staff. Protective eyewear is required, as is the absence of any reflecting surface in the operating theatre. Therefore the use of lasers requires special safety measures for the operating theatre. The financial investment is considerable, lasers cost between US$ 80000 and 100000. Maintenance costs are also high. American pioneers of LC used lasers only to coagulate and dissect despite the fact that their first publications spoke of "laser laparoscopic cholecystectomies." Recent cost-efficacy studies in the United States comparing lasers with electrocauteries have concluded in favour of the latter, which is less costly (US$ 10000–20000), easier to maintain, and simpler to use.

Technical Variants in Patients with CBD Stones

In state-of-the-art laparoscopic surgery, LC is not a first-line operation for a patient who has both symptomatic CBD stones and gallstones. First, we believe that the CBD must be cleared of any calculi by endoscopic sphincterotomy. The day after, LC is used to treat the gallstone disease provided there is no post sphincterotomy hyperamylasaemia. In our experi-

Fig. 16.38. Choledocoscopy performed through the cystic duct during an LC



ence, every patient for LC who has no clear symptoms indicating the presence of a CBD stone should have a preoperative work-up to exclude silent ductal stones. Our first 100 patients had both a preoperative work-up with ultrasonography and biochemical tests for cholestasis (alkaline phosphatase, gamma-GT), plus an intraoperative cholangiography. The latter never gave any additional information. Therefore, in routine practice, we propose the following. If ultrasonography reveals a CBD calibre greater than 8 mm, we opacify it by endoscopic retrograde cholangiopancreatography (ERCP); frequently an asymptomatic stone is discovered which is removed by endoscopic sphincterotomy. Here, LC is performed later on. If ultrasonography proves normal and alkaline phosphatase and gamma-GT are high, we also perform radiological opacification of the CBD, by tomographic intravenous cholangiography or ERCP in thin or fat patients respectively. When a stone is discovered, it is removed by endoscopic sphincterotomy before LC. If both ultrasonography and the biochemical tests for cholestasis prove normal, we do not perform preoperative cholangiography.

However, in certain circumstances, the preoperative work-up is inconclusive. It then becomes necessary to perform intraoperative cholangiography, all the more if the calibre of the cystic duct appears to be greater than 2 mm at laparoscopy. We have already described this technique. If one or more CBD stones are discovered, their extraction is attempted through the cystic duct with a Dormia basket. If extraction through the narrow cystic duct is not possible because of the size of the stone, we use a coronary dilatation balloon-type probe to dilate the cystic duct. Basket extraction is then attempted. Such extraction is quite a delicate process when small stones occur in an enlarged bile duct. Moreover, only stones situated downstream from the opening of the cystic duct are accessible. If extraction is not possible, one may perform cholangioscopy with a very fine fibrescope (1.8–2-mm diameter) inserted into the opening of the cystic duct (Figs. 16.38, 16.39). These fibrescopes have an operating channel which enables the insertion of a pulse laser fiber of 300-nm diameter (Fig. 16.40). It then becomes possible to fragment the stones under visual control and to push the fragments by irrigation through the papilla into the duodenum. However, this sophisticated technology is not available in many centres, so if mechanical transcystic extraction of stones is not possible, it is necessary to establish biliary drainage by a catheter inserted into the stump of the cystic duct and secured in place with an endoligature. LC is then completed as described above, and treatment of the residual CBD stone, is delayed until a later date. If the bile duct is narrow (4–8 mm) with a stone smaller than or equal to 2 mm, its spontaneous elimination may occur through the papilla. The Oddi sphincter of such patients is relaxed by an antispasmodic agent administered on a long-term basis. If the stone(s) are equal to or exceed 2 mm, there is no point in waiting and they should be removed by endoscopic sphincterotomy.

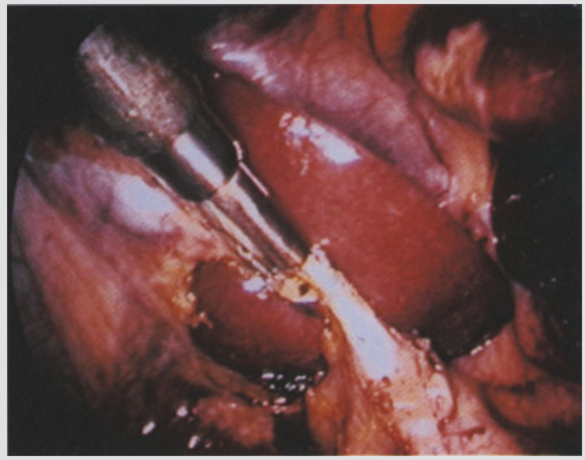


Fig. 16.39. Introduction of cholangioscope into cystic duct

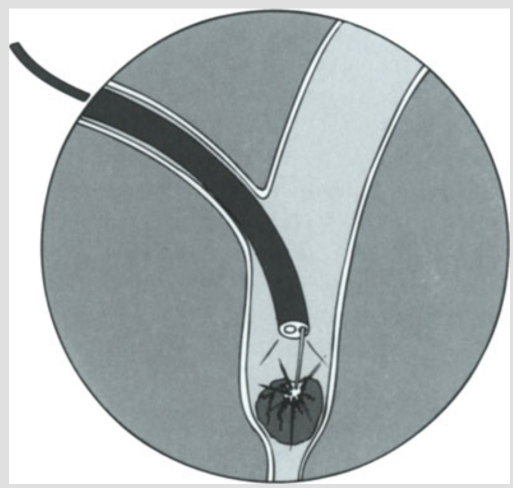


Fig. 16.40. Fragmentation of a CBD stone by pulse laser introduced through the cystic duct during an LC

Results

Course Without Complications

From November 1988 to January 1991, we performed 400 LC. Detailed results are shown in Tables 16.2–16.4. Operating time was between 20 and 182 min (mean, 70 min). The presence of perivascular adhesions doubled the operating time. Mean postoperative hospitalization was 4 days, 30% of patients remained in hospital 1 night and 30% 2 nights. We performed a survey regarding convalescence time and the date at which professional activity among the 100 patients operated on with a 1-year follow-up. On average, normal physical activity was possible 6–8 days after intervention. As for convalescence, this averaged 20 days. The date at which work was resumed depended on the patient's profession and social status, rather than on the type of intervention itself. In our series we found no secondary or late organic complication at 1-year follow-up.

Mortality

For a long time, pioneers of this technology had no mortality during LC. Without doubt, this was due to very rigorous patient selection in which patients at high cardiorespiratory risk were excluded from the intervention. In our series one death occurred after over 300 patients had been treated. Autopsy could not be performed so the cause of this sudden death remains unknown. With the subsequent drop in the level of selection criteria and the greater number of patients, postoperative deaths are now appearing. They remain within the limits of overall mortality for traditional cholecystectomy (0.1%). In a Franco-Belgian survey (Table 16.3) [16], there were five (0.1%) deaths among 3708 patients, of which two were of unknown cause. The others were due to one uncontrolled bleeding, one acute pancreatitis after endoscopic sphincterotomy, and one myocardial infarction.

Table 16.2. LC – November 1988–January 1991 (n=400) Age range 13–83, Males=76, Females=324

	n	%
Mortality	1	0.25
Complications	9	2.2
Laparotomy Conversions	13	3.2
CBD Injury	1	0.25

Table 16.3. LC – series of 3708 cases in France and Belgium – June 1991

	n	%
Mortality	5	0.13
Morbidity	133	3.5
Laparotomy Conversions	273	7.3
CBD Injuries	7	0.18

Table 16.4. LC – nine postoperative complications among 400 cases

Managed Conservatively	
1 Bile fistula	
1 Acute pancreatitis	
1 Pulmonary infection	
1 Parietal haematoma	
Managed Endoscopically	
1 Bile fistula (endoscopic sphincterotomy)	
1 Subhepatic Abscess	Laparoscopic drainage
2 Abscesses of Douglas pouch	Laparoscopic drainage
Managed by open surgery	
1 Partial obstruction of CBD due to the clip on the cystic artery	

Complications

The main recent data indicate a rate of 2%–4% for postoperative morbidity (Table 16.4); the same is true of our series and the Franco-Belgian one [17]. These complications are due to secondary bleeding or septic collections. They may also be due to a CBD lesion. Most are managed conservatively or with a second laparoscopy. Apart from exceptional circumstances (e.g., severe secondary bleeding), the decision to perform laparotomy should not be taken without prior investigation. When secondary bleeding or intra-abdominal collection is suspected, we do a morphological work-up including CT scan and ERCP. In this way the following may be revealed: the presence and extent of collections; any foreign bodies such as stones forgotten in the abdominal cavity during a painstaking extraction of the gallbladder; and a biliary leak clearly apparent on ERCP. Usually a second laparoscopic approach allows the confirmation and evacuation of these collections. Often the cause of bleeding or biliary leak remains unknown, but simple postlaparoscopic drainage solves the problem.

It is sometimes possible with laparoscopy to deal with small biliary leak from the CBD without loss of ductal continuity by inserting a T-tube drain. If the biliary leak seems minimal on ERCP and if there is no large collection around it, simple endoscopic sphincterotomy can dry the bile leakage. Only the discovery of a site of bleeding which cannot be controlled by laparoscopy, a major lesion of the CBD, i. e., loss of ductal continuity, or partial or total obstruction due to misplaced clip during the first intervention are indications for open surgical approach. In our series, we have had no complications due to the creation of the pneumoperitoneum. In the Franco-Belgian series, these were extremely rare (less than 0.1 %). However, we stress the importance of correctly insufflating the peritoneal cavity, a technique requiring very precise training. Certain series report higher rates of complications [18–20]. In general, complications are equal to or lower than those following open cholecystectomy, the percentage of CBD damage varying between 0.2 % and 0.4 %.

Conversions to Laparotomy

One of the main advantages of this laparoscopic technique is that it can, in the hands of a biliary surgeon, be converted as required to open surgery without having to change the anaesthetic protocol or position of the patient. The conversion rate varies between 4 % and 8 %, and depends on the surgeon's experience, the state of the disease, and on how LC is performed (Table 16.5). The most frequent cause for conversion is extensive local inflammation, making the recognition of vascular and biliary components difficult. Difficult haemostasis and uncertainty regarding the exact anatomy of the biliary components should lead the surgeon, without losing face, to convert to the traditional open technique [21]. The same is true if any one of the various devices required for laparoscopic surgery fails. Poor-quality imaging and an unstable pneumoperitoneum should also lead to conversion. In this respect, the surgeon relies heavily on the equipment.

Table 16.5. LC – 13 laparotomy conversions among 400 cases

5 Severe bleeding	1 Liver bed
	2 Cystic arteries
	2 Portal hypertension
6 Tight adhesions with colon-liver parenchyma	
1 Rupture of gallbladder during intracorporeal lithotripsy	
1 For CBD stone removal	

Conclusions

Begun in anonymity in Lyon, France, in March 1987 by Mouret and performed discreetly in an atmosphere of scepticism and even hostility in 1988, LC hit the headlines in 1989. The quality and consistency of initial results explain the extraordinary interest that this technique is arousing. Indeed, the public now demands it. It has rapidly become widespread, but this did not happen without causing serious safety problems. Unlike urological, orthopaedic, and gynaecological surgeons, general and digestive surgeons in particular have long shied away from using endoscopy in their interventions. Most have received no specific training in laparoscopy. At present, the centres specialized in these new techniques are not able to provide enough in-service training and teaching. The situation has occurred in which clinicians began to use this surgical technique without sufficient technical experience. Considerable efforts are now being made by the universities and the most prestigious scientific societies together with companies producing such equipment to ensure that this new surgical technique is taught adequately.

Although the problem of training is now being solved as regards the young surgeons of the future, the same is not true for established surgeons. We recommend the latter to go along to the gynaecological departments which regularly perform laparoscopic surgery on a wide scale and to familiarize themselves with the safe creation of a pneumoperitoneum and with inserting instruments without causing trauma. Secondly, they should attend courses which provide practical experience on phantoms and animals. Finally, they should visit and acquire in-service training in a department specialized in laparoscopic digestive surgery. The length of such training depends on the clinician's pre-existing knowledge regarding digestive surgery; well-trained surgeons can start laparoscopic surgery on their own after assisting at a dozen interventions. For the first 50 cases we would advise them to be extremely selective regarding indications and obtain the initial experience on patients without previous episodes of acute cholecystitis.

LC is the first shining example of the success of endoscopic surgery, which obviates all the disadvantages of opening the abdominal or thoracic wall [22]. It is the surgeon's gateway to the future. Its prerequisite is a thorough apprenticeship and any premature practice could unjustly be prejudicial to a technique whose results indubitably point in the direction of progress.

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17 Laparoscopic Gallstone Extraction

B. Mentges, E. Frimberger, and G. Buess

Introduction

Since the early 1970s several minimally invasive methods have been developed to replace conventional cholecystectomy in the therapy of symptomatic cholelithiasis. Oral litholysis (OL) and extracorporeal shockwave lithotripsy (ESWL) have several disadvantages. Despite restricted indications and prolonged medical therapy not all treated patients become stone-free. Remaining stone debris and sludge act as a nidus for new stone formation. In percutaneous cholecystolithotomy [5] or percutaneous transhepatic litholysis (PTL) [1, 4, 7] calculi can be crushed by direct lithotripsy or dissolved by methyl *tert*-butyl ether (MTBE) application. Because of the inability to close the gallbladder, drains are inserted and remain in place for up to ten days. The laparoscopic cholecystotomy combines low invasiveness with high efficacy. The patients are stone-free immediately, calcified stones can be removed as well, the gallbladder is closed by a clip, and further drug therapy is not necessary. There are reports in the literature about a correlation between cholecystectomy and colonic cancer [6] and about new complaints after cholecystectomy [2]. Thus, preserving a functioning contractile gallbladder seems to be a logical concept provided that selection of patients with a low tendency towards new stone formation is practiced in order to keep stone recurrence at a low level. After two years of development, laparoscopic cholecystotomy is ready for clinical introduction.

Indications

Only patients with a functioning contractile gallbladder are suitable for laparoscopic cholecystotomy. The rate of recurrent stones after ESWL is lower in patients with solitary stones than in patients with multiple calculi. Patients with stone formation at an early age should be excluded because of the increased lithogenesis. Therefore, the ideal patients for laparoscopic cholecystotomy are those over 50 years of age with one to three stones in a contractile gallbladder.

Preoperative Diagnosis

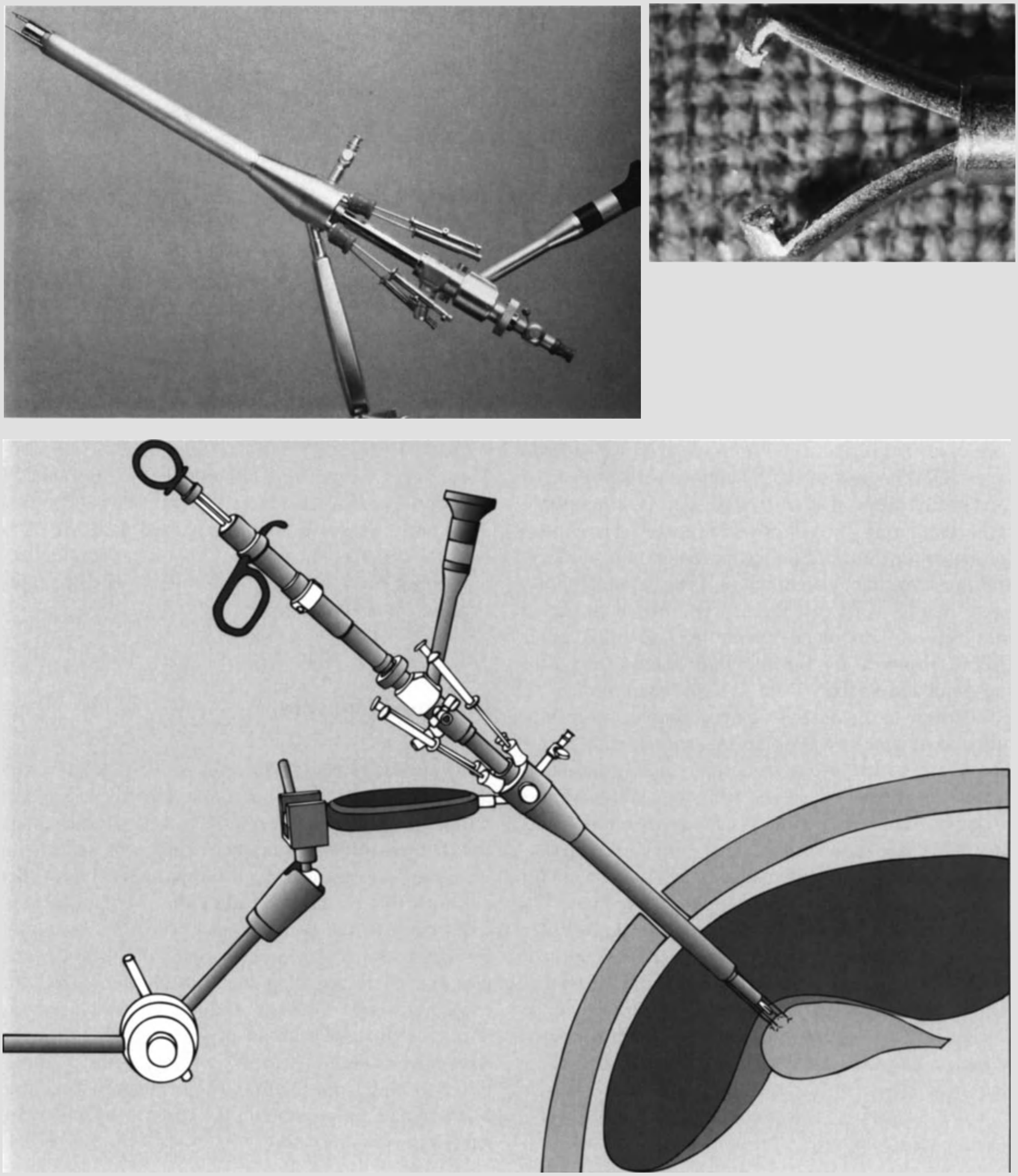
The contractility of the gallbladder has to be proved by sonography before and after a fatty meal. The longitudinal and transverse diameter should decrease 30% from the original values. Scout X-rays or computed tomography for determination of the rate of stone calcification are not necessary.

Informed Consent

As laparoscopic cholecystotomy is still under development, the patient has to be fully informed. Laparoscopic cholecystotomy is only one form of treatment in the interdisciplinary therapy of cholelithiasis. Therefore, the patient has to be informed also about other methods of treatment. In the case of complications, conversion to the conventional procedure – namely cholecystectomy – is conceivable. Complications are possible on introducing the Veress needle and the cholecystoscope into the abdominal cavity, namely damage to intra-abdominal organs. Bleeding from the liver can be caused by strong traction on the gallbladder. Bleeding from the fundus of the gallbladder and bile leakage are possible in the case of defective closure of the puncture hole.

Anaesthesia

After introduction of the method into the clinical routine, a procedure under local anaesthesia is conceivable. A sedative should be applied before the opening of the gallbladder.

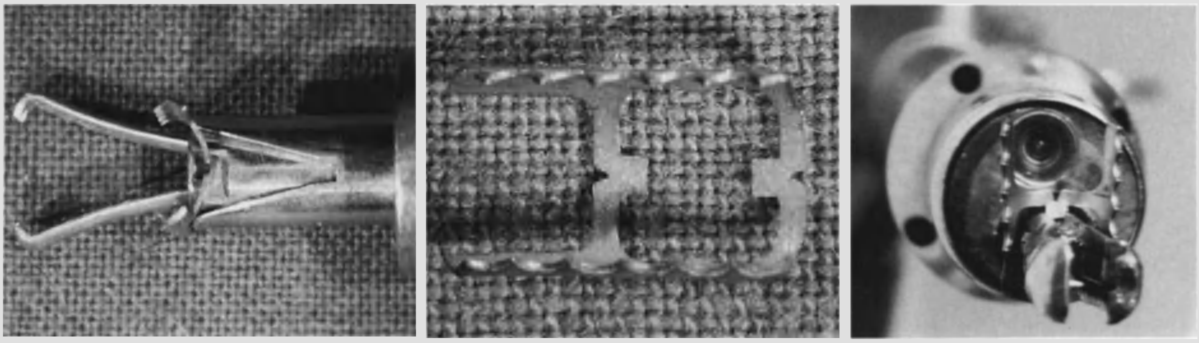


a

b

c

Fig. 17.1. **a** Cholecystoscope; **b** application of cholecystoscope; **c** graspers



a b, c

Fig. 17.2. **a** Clip forceps; **b** clip; **c** operating telescope with clip forceps introduced into the working channel, telescope looking through the asymmetrical part of the clip

Patient Positioning, Skin Preparation and Draping

Laparoscopic cholecystotomy is performed with the patient in a supine position. Skin preparation and draping are the same as in conventional cholecystectomy, i. e. the whole abdominal wall must be sterile and free from drapes.

Layout of Ancillary Instruments and Positioning of Staff

The operator stands on the left side of the patient, facing the assistant. The video equipment is positioned on the right side in the operator's field of view. The light source for the operating telescope and the steering device of the single-chip camera are accommodated in the video tower. The scrub nurse and the instrument table are located at the foot of the operating table. The CO_2 insufflation device is situated on the left side of the patient. The double ball-and-socket joint (Martin, Inc.) for fixation of the cholecystoscope is connected to the left bar of the operating table.

Instruments and Equipment

The following instruments are specially designed for the procedure:

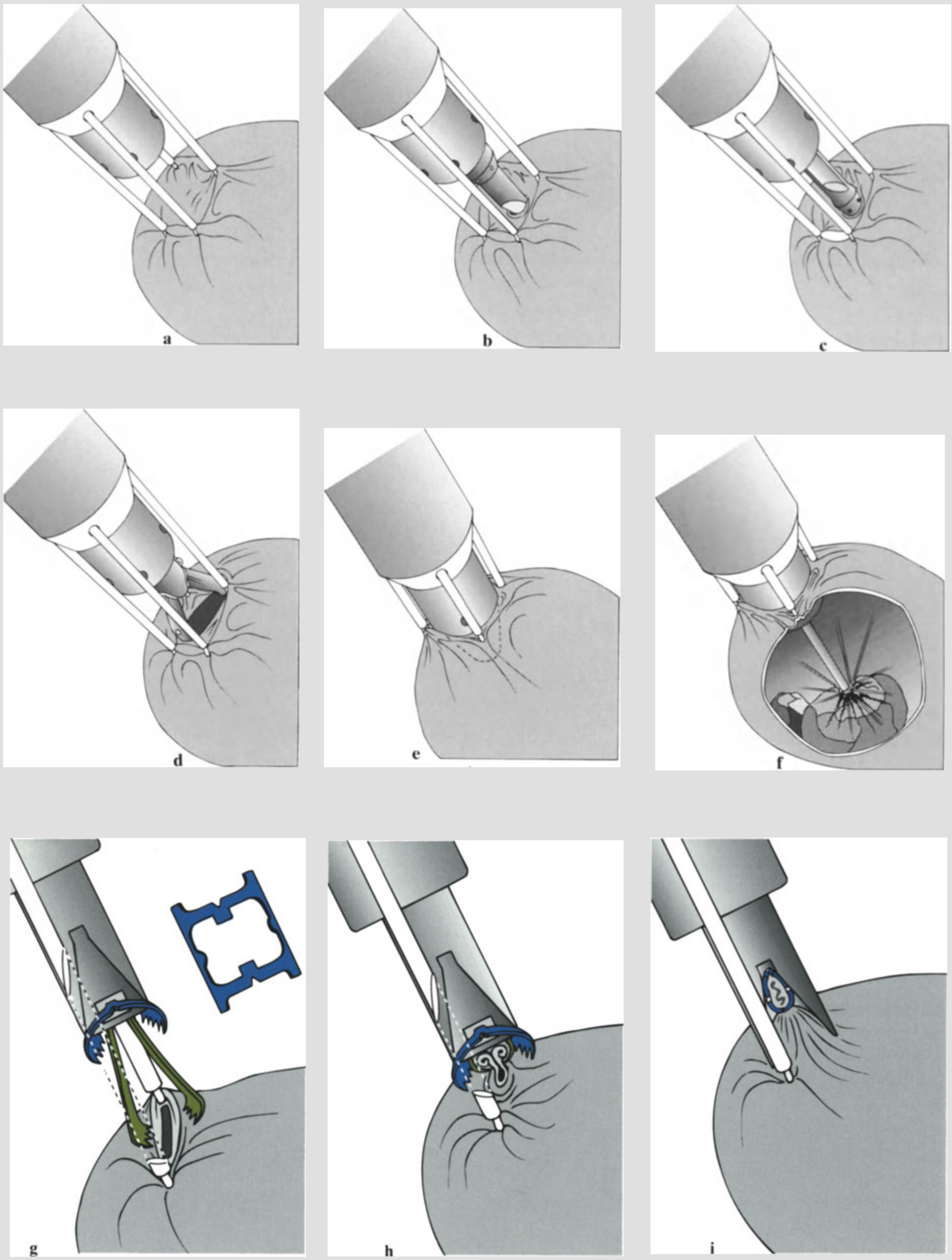
- Cholecystoscope (Fig. 17.1 a)
- Puncture cannula with olive tip
- Puncture cannula with dilatation balloon
- Dilatation forceps for opening the puncture in the gallbladder wall
- Clip forceps, clips (Fig. 17.2)
- Dilatation cone with 3.3-mm channel for the straight telescope

The following standard devices and instruments are also used:

- Operating telescope with oblique eyepiece, 0° angle of view, 10-mm diameter, 5-mm working channel
- Straight telescope, 3.3-mm diameter, 5° angle of view, for insertion into the dilatation cone
- CO_2 insufflator
- Aspiration/irrigation unit
- Light source
- Ultrasound lithotripter, electrohydraulic lithotripter, pulsed dye laser
- Double ball-and-socket joint Martin's arm
- Laparoscopic instrument set

The Operating Cholecystoscope

The operating cholecystoscope (Fig. 17.1 a, b) has an outer diameter of 14 mm and a working channel of 10 mm. Four channels for grasping instruments run inside the wall of the instrument. The graspers consist of metal tubes with a diameter of 1.8 mm, which are inserted through ports sealed by rubber caps and advanced to the operating area. The section of tube extending into the operating area is slightly angled, increasing its effective radius when the handle is rotated. The handles of the tubes control two wire arms which are advanced out of the tubes and opened to grasp the gallbladder (Fig. 17.1 c).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The Puncture Cannula with Olive Tip

This cannula has an olive-shaped tip which is inserted into the gallbladder to prevent leakage of bile after puncture and removal of the obturator (Fig. 17.3 c).

The Puncture Cannula with Dilatation Balloon

The puncture cannula with the dilatation balloon is a combined instrument which is still under development. After puncture of the gallbladder, irrigation and aspiration, the cannula is advanced further and the balloon brought into the area of the puncture. When inflated, the balloon is dumbbell shaped to prevent the gallbladder wall from slipping off during dilatation.

The Clip Forceps

The two arms of the clip forceps are not used to insert the clips but to grasp and approximate the edges of the opening in the gallbladder. They can be advanced out of the sheath of the forceps by means of the handle (Fig. 17.2 a). The clips are right-angled metal frames, 7–10 mm long (Fig. 17.2 b). They are fixed at the tip of the sheath. After approximation of the edges of the gallbladder opening with the jaws of the clip forceps, (Fig. 17.3 h) the outer tube is advanced and the clip bends in the middle and closes over the wound (Figs. 17.3 i, 17.6).

Surgical Technique

After establishment of a pneumoperitoneum by means of a Veress needle, a perpendicular incision of 1.5 cm is made directly above the umbilicus. The cholecystoscope is inserted and pushed through the abdominal wall using a 10-mm trocar. After localization of the gallbladder, the handle of the cholecystoscope is connected with a double ball-and-socket joint and fixed in the operating position. A one-chip camera is inserted into a long sterile bag and attached to the eyepiece of the telescope. The operative manipulations are recorded and followed on the video screen. The fundus of the gallbladder is gripped by the four graspers, which are then rotated until an area of stretched wall is obtained which can be punctured with the cannula (Fig. 17.3 a, b, 17.4 a). After irrigation and aspiration, the puncture is positioned on the narrow end of the dilatation olive. Following dilatation, the graspers are relocated directly on the edges of the puncture and used to pull it over the proximal part of the dumbbell-shaped olive, which is exactly aligned with the cholecystoscope to allow it to be pulled over the instrument smoothly. As an alternative, the dilatation can be performed with a dilatation forceps (Fig. 17.3 d, 17.4 b) and the gallbladder pulled onto the instrument smoothly (Fig. 17.3 e, 17.4 c) after inserting a dilatation cone with the 3.3-mm telescope. After inserting the operating telescope into the gallbladder (Fig. 17.1 b), stones smaller than 10 mm can be extracted through the working channel of the cholecystoscope using a grasping forceps (Fig. 17.5). Bigger stones are fragmented by an ultrasound lithotripter, an electrohydraulic lithotripter or a pulsed dye laser (Fig. 17.3 f). The gallstone fragments are removed by irrigation and aspiration. The gallbladder is then checked for remaining fragments by the telescope. It can be distended by CO_2 insufflation to smooth out the folds and improve the view. The gallbladder is then freed from the instrument, two graspers released and the two remaining opposite graspers rotated outwards until the puncture forms a slit (Fig. 17.3 g), which can be closed with a stainless steel clip (Fig. 17.6). The clip is 10 mm in length, and therefore the operating telescope is first removed, the clip forceps inserted into the working channel and then the clip placed in the clip forceps. It is important to correctly orientate and fix the clip forceps in position with a locking screw. Because of the asymmetrically located working channel of the telescope (below the optical system) the asymmetric part of the clip must point upwards to fit through the working channel of the cholecystoscope (Fig. 17.2 c). After attachment of the clip, the clip forceps-telescope unit is inserted into the cholecystoscope, the edges of the puncture hole are approximated by the branches of the clip forceps and the hole is closed by the clip.

Fig. 17.3. **a** Fixation of the gallbladder by the graspers of the cholecystoscope. **b** Puncture of the gallbladder. **c** Retraction of the mandrin and introduction of the cannula with olive-shaped tip. **d** Dilation of the puncture hole. **e** Gallbladder being pulled onto the cholecystoscope. **f** Crushing of a gallstone with a lithotriptor. **g** Clip forceps with extended arms and clip. The gallbladder hole is formed to a slit by rotating outwards the two remaining graspers. **h** The edges of the gallbladder hole are approximated by the arms and pulled to the shaft of the clip forceps. **i** The clip is closed by advancing the outer tube of the clip forceps

a

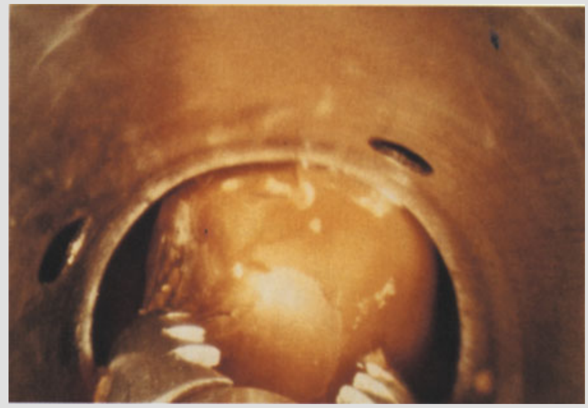
b

c

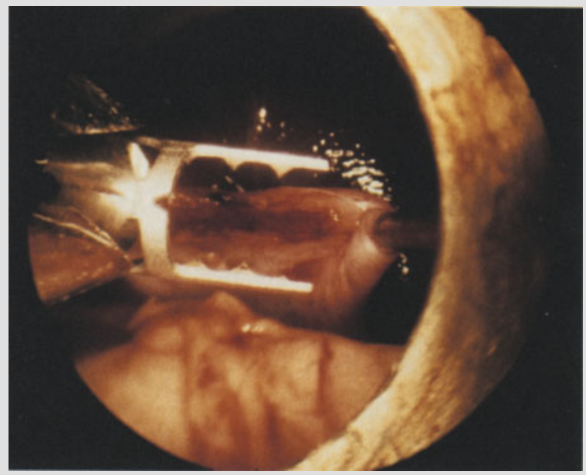
Fig. 17.4. a–c Fixation, puncture and dilation of the gallbladder. Introduction of the cholecystoscope

Postoperative Treatment

After it has become clinically established laparoscopic cholecystotomy may well be performed under local anaesthesia, so the patient can be discharged from the hospital the same day. Follow-up examinations are recommended one, six and twelve months postoperatively and yearly thereafter. Among other examinations, ultrasonography is indispensable.



17.5



17.6

Fig. 17.5. Stone extraction with forceps

Fig. 17.6. Clip application

Results

Laparoscopic cholecystotomy with two puncture sites was described by Frimberger in 1979 [3] and clinically introduced in 1990. The gallbladder is fixed by a forceps which is introduced via a separate access, whereas opening of the organ by high-frequency current, extraction of the stone and closure of the gallbladder with several clips is performed through the main puncture site. In the latest analysis of his case material Frimberger (personal communication) reported on 21 patients operated upon using his method in the period from February 1, 1990 to October 1, 1991. In one case the procedure could not be performed because of strong adhesions which had formed after a previous operation. A maximum of eight stones were removed, and in one case two polyps were resected. Conventional cholecystectomy had to be performed owing to complications in two patients in the early stages of clinical use of the new laparoscopic technique, when a catheter was placed into the gallbladder instead of closing it with clips; bleeding into the gallbladder was observed in one of the two patients with subsequent conventional cholecystectomy and bile leakage because of a catheter dislocation in the other. During the follow-up one patient reported persisting complaints. Recurrent stones could not be diagnosed sonographically in any of the 20 patients.

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18 Cholecystostomy Drainage for Severe Acute Cholecystitis

A. Cuschieri

Introduction

Although routine cholecystectomy in the fit adult is safe and carries a low mortality, emergency surgery for acute cholecystitis in the elderly carries a reported mortality of 9.8%–12.5% from postoperative cardiorespiratory complications. Furthermore, these patients are at a greater risk for the development of empyema which doubles the mortality figures. In addition to being immunocompromised, elderly patients have intercurrent cardiorespiratory disease which enhances the anaesthetic risk and contributes significantly to the postoperative mortality. Cholecystectomy is also a high-risk procedure in cirrhotic patients.

In these high-risk groups a relatively minor percutaneous intervention which can effectively and safely drain the acutely inflamed gallbladder can tide the patient over the critical period. Drainage of the inflamed gallbladder is best achieved by the laparoscopic route. This approach is safer than the percutaneous method performed under radiological control since the risk of damage to the hepatic flexure of the colon is obviated.

Types of Acute Cholecystitis and Endoscopic Management

From the classical pathological standpoint, three types of acute cholecystitis are recognized: acute obstructive (calculous) cholecystitis, acute acalculous disease and acute emphysematous cholecystitis.

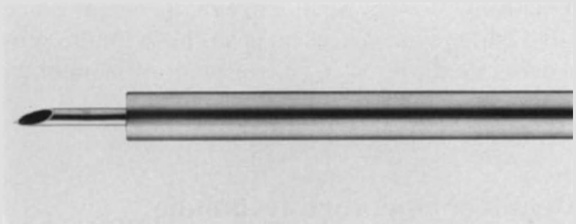
Acute Obstructive Cholecystitis

Acute obstructive cholecystitis is the most common and is usually a self-limiting disease in that the acute inflammation resolves with conservative management, permitting delayed or interval cholecystectomy. A significant percentage of these patients, however, have severe disease which progresses to more serious pathological states: gangrenous cholecystitis with or without perforation and empyema of the gallbladder. Hence the tendency for early cholecystectomy performed soon after the diagnosis is made, which is now practised routinely in many centres. The other disadvantages of delayed or interval cholecystectomy which have been confirmed by several prospective clinical trials include recurrence of the disease whilst the patient is awaiting definitive therapy and increased overall cost of treatment.

Opinion is divided with regard to the use of laparoscopic cholecystectomy in the treatment of patients with acute obstructive cholecystitis. Some surgeons maintain that this practice is safe, whereas others consider acute cholecystitis to be a relative contraindication. In the author's view, this controversy is explained by the fact that the clinical as opposed to the pathological diagnosis of "acute cholecystitis" covers a wide spectrum of morbid conditions occurring in patients whose general condition and fitness for surgical intervention also varies.

One prospective study has shown that at least 30% of patients coming to surgery within days of acute cholecystitis being diagnosed *do not have macroscopically apparent acute inflammation of the gallbladder.* These patients are, of course, suitable candidates for laparoscopic cholecystectomy. Other patients have *oedematous cholecystitis* where the gallbladder is pink, tense and slightly oedematous. These patients can also be safely treated by laparoscopic cholecystectomy, and indeed the slight oedema facilitates somewhat the dissection of the cystic pedicle. Aspiration of the liquid contents of the gallbladder (Fig. 18.1) by decompression of the organ enables the surgeon to grasp it more efficiently. There is no need for suture closure of the perforation as leakage is minimal, especially if the gallbladder is grasped at the site of needle puncture.

Other patients are found to have a grossly distended, rather thin-walled gallbladder with few adhesions to surrounding organs – *empyema or mucocoele or hydrops.* Provided the vascular integrity of the gallbladder wall is assured, the patient is fit, and, following decompression as outlined above, these patients are



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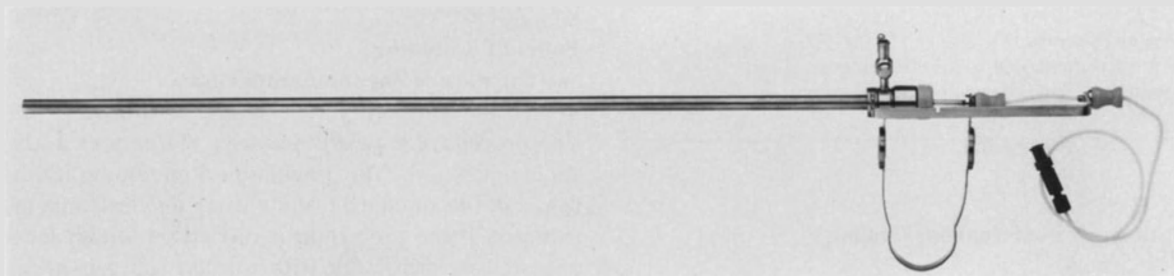

b

Fig. 18.1 a, b. Instruments for aspiration of the inflamed gallbladder. **a** The puncturing needle (Storz), the hub of which seals the perforation during suction of the contents. **b** The Frimberger instrument for puncturing and rinsing (Storz)

suitable candidates for laparoscopic cholecystectomy. The only technical problems which are frequently encountered in these patients are the thinness of the gallbladder wall, which is prone to rupture if excessive traction is applied, and a large stone impacted in Hartmann's pouch, which renders dissection of the cystic duct difficult though not impossible.

There are, however, patients in whom the pathological process precludes safe performance of cholecystectomy by the laparoscopic route. These include adherent *indurated acute cholecystitis* and *gangrenous disease* with or without localized perforation. In indurated cholecystitis, the organ is fleshy with grossly thickened "leathery" walls which make it impossible to grasp the fundus even after attempted decompression. Adhesions to omentum and surrounding organs are numerous and vascular, and the cystic pedicle is grossly thickened, contracted and fleshy. These patients and those with gangrenous disease are best treated by open cholecystectomy.

Acute Acalculous Cholecystitis

The accepted method of treatment of this life-threatening condition of unknown aetiology is by open cholecystectomy. These are poor-risk patients often receiving intensive care therapy in whom a quick expeditious surgical intervention is needed to overcome the crisis. An alternative treatment which has been introduced in recent years is percutaneous cholecystostomy drainage. In a series reported from Rotterdam, complete recovery of gallbladder function was demonstrated with recovery after percutaneous decompression by subsequent follow-up. These patients are thus candidates for laparoscopic or radiologically controlled cholecystostomy drainage performed under local anaesthesia and intravenous sedation as an alternative to open cholecystectomy.

Emphysematous Cholecystitis

Emphysematous cholecystitis is due to a mixed infection with anaerobic gas-forming organisms and is encountered in the elderly and in diabetic patients in whom it is associated with thrombosis of the cystic artery. There is no place for laparoscopic cholecystectomy or cholecystostomy in the surgical treatment of this highly lethal condition.

Percutaneous Drainage for Inflamed Gallbladder

Indications and Contraindications

These are listed in Table 18.1. By far the most common situation necessitating simple drainage of the acutely inflamed gallbladder is acute cholecystitis/empyema in poor-risk, elderly patients and in those with significant cardiorespiratory disease. These patients can be tided over the critical illness by this simple procedure. Subsequent to recovery, definite management can be considered and is individualized in accordance with the residual condition of the patient.

Table 18.1. Indications and contraindications for laparoscopic cholecystostomy drainage

Indications
Acute acalculous cholecystitis
Acute cholecystitis in the elderly
Acute cholecystitis in patients with severe cardiorespiratory disease
Severe acute cholecystitis encountered during attempted laparoscopic cholecystectomy
Contraindications
Perforated cholecystitis – localized or generalized
Gangrenous acute obstructive cholecystitis
Emphysematous cholecystitis

Options for Percutaneous Drainage

Decompression of the gallbladder can be achieved in three ways:

1. Percutaneous subcostal or transhepatic drainage under radiological/ultrasound control
2. Laparoscopic cholecystostomy
3. Minicholecystostomy of Burhenne and Stoller

The benefits of laparoscopic cholecystostomy over the radiological procedure include assessment of the disease severity with exclusions of gangrenous disease (which is a contraindication for percutaneous drainage) and the avoidance of trauma to the hepatic flexure. In this context, one anatomical computed tomography (CT) study has shown that the colon is anterior to the fundus of the gallbladder in 13% of patients.

Preparation of Patient for Laparoscopic Cholecystostomy

The diagnosis is usually made by the clinical picture and physical findings and is confirmed by ultrasound examination and gallbladder scintiscanning. Antibiotic therapy and intravenous crystalloid solutions are administered together with opiate analgesia for pain relief.

Anaesthesia

The procedure is best performed under general anaesthesia, but if the condition of the patient precludes this, local infiltration anaesthesia with 1% lignocaine and intravenous sedation with midazolam is used. Alternatively, lower right intercostal nerve block (10–12th) provides excellent anaesthesia for this procedure. Cardiovascular and respiratory monitoring are essential throughout the operation.

Details of Operative Technique

Patient Positioning and Creation of Pneumoperitoneum

The procedure is performed with the patient in the supine position. The pneumoperitoneum is established in the standard fashion using an electronic insufflator. If the procedure is carried out under local anaesthesia, insufflation with nitrous oxide causes less discomfort than CO_2. However, the use of the former gas precludes use of electrocautery with safety. In high-risk patients, a tense pneumoperitoneum should be avoided and for this reason, the intra-abdominal pressure should be kept below 10 mm Hg.

Cannulae Insertion

The telescope cannula (11.0 mm) is inserted in the standard subumbilical region. Under direct vision, a second trocar and cannula (5.0 mm) is inserted in the left upper quadrant for use of the palpating probe which is necessary to obtain exposure of the inflamed gallbladder. This is often obscured by adherent omentum and mesocolon. With the palpating probe, enough of these adhesions are teased away to expose the fundus of the gallbladder.

Evacuation of the Gallbladder Contents

Although there are specially designed instruments such as that developed by Frimberger for puncturing and rinsing the gallbladder, in the author's view the most useful instrument for dealing with the inflamed gallbladder is the Mayo-Oschner suction trocar and cannula which is available in three sizes (Fig. 18.2). The important features of this instrument are: an integral suction port, complete occlusion of the cannula lumen when the trocar is held in full projection and a screw-cap seal on the cannula top which prevents contamination during evacuation of the gallbladder contents. The appropriate site for insertion of the Mayo-Oschner cannula is selected by finger depression. This should be as close as possible to the fundus of the in-

Fig. 18.2. Mayo-Oschner gallbladder suction trocar and cannulae

flamed organ. Following insertion through the parietes under vision, suction is attached to the side arm of the trocar and cannula assembly. The tip of the trocar is then directed towards the centre of the fundus, and, with a smart jab, the gallbladder is perforated and the cannula advanced into its lumen. As the cannula is held in place by constant pressure, the trocar is withdrawn above the suction port and the gallbladder contents evacuated. A specimen of the pus is taken for culture.

Insertion of Balloon Catheter

The suction line is detached, the screw cap undone and removed together with the trocar. An appropriately sized balloon catheter which fits inside the cannula (Fr 7–10, depending on the size of cannula used) is lubricated and then threaded down the cannula into the lumen of the gallbladder when the balloon is inflated with isotonic saline. Traction is then applied to the catheter as the cannula is exteriorized over it. Sustained traction on the balloon catheter achieves two objectives: it seals the entry site in the gallbladder, and shortens and straightens the tract from the organ to the parietes. Indeed, in many patients, the fundus may be made to reach the abdominal wall. The catheter is then sutured to the skin in the desired position and connected to a closed drainage system. The area is then sealed with an occlusive dressing. The cannula is pushed towards the end of the external part of the catheter and then simply strapped to the abdominal wall further down.

Apart from the removal of small calculi and debris during suction evacuation of the gallbladder contents, no attempt should be made at stone extraction of lithotripsy at this stage as the gallbladder wall is friable and thus easily perforated by the instruments. Likewise, rinsing of the gallbladder in unnecessary and may indeed be harmful by dislodging small calculi into the common bile duct and enhancing systemic absorption of endotoxin.

Alternative Technique

This is based on the coaxial catheter– guidewire–stiffener tube method and employs standard percutaneous biliary or nephrostomy sets with an Amplax sheath. The initial evacuation of the gallbladder contents is best performed using a small Mayo-Oschner cannula. The coaxial catheter– guidewire is inserted through the cannula which is then removed. In the context of drainage of acute cholecystitis, the stiffener tube-guided method is slower, more exacting and offers no advantage over the transcannular technique described above.

Postoperative Management

Antibiotic therapy is maintained for 5 days. A contrast examination is performed 24 h later. This establishes that the catheter has not become dislodged and also provides useful information regarding the pathological state of the biliary tract, the extent of the stone load and the presence of ductal calculi. Apart from being an essential safety check, the cholecystocholangiogram indicates the nature of the subsequent treatment to be undertaken when the patient has recovered from the acute episode.

Laparoscopic drainage of the inflamed gallbladder is a safe procedure and complications are rarely encountered. These include catheter dislodgement, bile leakage into the peritoneal cavity and bleeding. Damage to the hepatic flexure, which is a well documented complication of the equivalent radiologically controlled procedure, is obviated by the laparoscopic approach.

Subsequent Management

The management of these patients subsequent to their recovery from the acute illness depends on two considerations:

1. The general condition of the patient including age and cardiorespiratory state
2. The residual pathology of the gallbladder and biliary tract

Conservative Management

Some patients, such as the very old and infirm and those with decompensated cardiorespiratory disease, remain unsuitable for cholecystectomy, laparoscopic or otherwise. The safest option in this group consists of percutaneous gallstone clearance via the cholecystostomy tract. This is performed under intravenous sedation with midazolam and opiate analgesia, with visual control of the interior of the gallbladder obtained by the insertion of the flexible choledochoscope or rigid nephroscope. If the stones are large (>1.0 cm), they require lithotripsy. This may be mechanical using crushing forceps, ultrasonic, or by the application of pulsed dye laser. As there is a small risk of fragments entering the common bile duct during the fragmentation process, preliminary occlusion of the cystic duct by the insertion of a biliary balloon catheter is advisable (Fig. 18.3), though not generally practised.

Another option is the local instillation of methyl-*tert*-butylether (MTBE) to achieve chemical dissolution of cholesterol stones. In this high-risk group, preliminary occlusion of the cystic duct as outlined above is highly desirable to prevent escape of the MTBE into the biliary ductal system.

In patients who have recovered from acute acalculous cholecystitis, the cholecystostomy drainage tube is removed after inspection of the mucosa of the gallbladder by the flexible choledochoscope or rigid nephroscope to confirm the absolute integrity of the gallbladder mucosa.

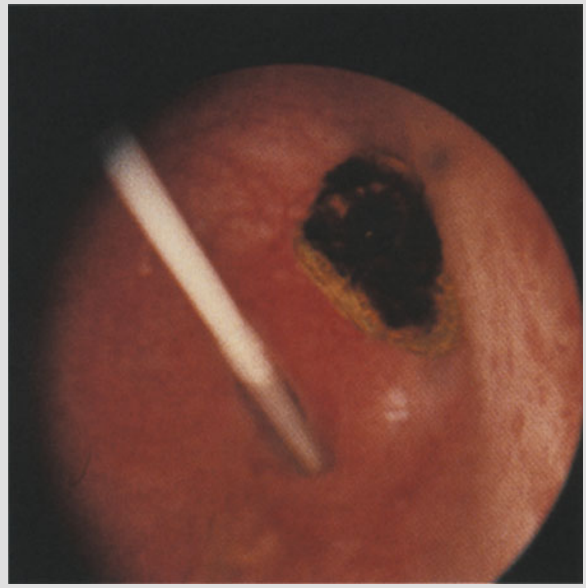

Fig. 18.3. Occlusion of the cystic duct by a biliary balloon catheter to prevent migration of gallstone fragments into the common bile duct during lithotripsy. The same technique can be used during percutaneous dissolution of cholesterol stones by MTBE applied through the cholecystostomy tract

Operative Management

The remaining patients are treated with interval cholecystectomy some 4–6 weeks later. The cholecystostomy drain should be left in situ attached to a closed drainage system until the operation. Apart from the safety aspect, the retention of the cholecystostomy drainage considerably facilitates the dissection of the gallbladder from the anterior abdominal wall during cholecystectomy. Whether this is performed laparoscopically or by the open technique is largely dependent on the experience of the surgeon and the extent of adhesions encountered at the preliminary laparoscopic inspection.

Chemical Cholecystectomy – Future Option

A number of groups are developing sclerosant methods for the destruction of the gallbladder mucosa using a variety of agents (sodium hydroxide, absolute alcohol, trifluoroacetic acid, etc.) which are instilled into the gallbladder lumen and, following the appropriate contact time, removed with subsequent saline lavage. Although the technique has only been applied experimentally both in small and large animals, there is no doubt that it is feasible. The method relies on safe and full proof occlusion of the cystic duct prior to the instillation of the sclerosant into the gallbladder. Ingenious methods for achieving cystic duct occlusion including radiofrequency electrocoagulation have been described. Currently, the method has three limitations which require further evaluation before the technique can be applied to the human: regeneration of the gallbladder mucosa from the cystic duct, toxic phenomena related to the absorption of the sclerosant and the risk of gallbladder cancer in the long term. The last consideration does not apply, however, to patients with limited life expectancy such as the aged and the infirm in whom chemical cholecystectomy may be a very sensible option in the near future.

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19 Laparoscopic Management of Inguinal Hernias – A Preliminary Report

R. Ger

Introduction

The repair of an inguinal hernia is largely dictated by the origin of the hernia. In the past some considered all hernias to be congenital, that exicision of the sac was curative, and that anything else, such as suturing muscle layers, was unnecessary and meddlesome [1]. It was also proposed at that time that some types of direct hernias are congenital, such as a diverticular type of hernia that protrudes through a congenital defect in the conjoined tendon. These opinions, held by some at the end of the nineteenth century, do not find many adherents towards the end of the twentieth century. Anatomic descriptions of the inguinal area continue to flourish; this would have infuriated Tait, who, in the days where prolonged and intensive anatomic dissections were the rule, stated that, "I have come to one conclusion absolutely, and that is that the wearisome minutiae of anatomy insisted upon in this subject are not only wholly useless but they are mischievous."

Viewpoints on the internal ring continue to stimulate interest. Tait stated, "I have the impression that the radical cure of hernia, other than umbilical, will, by and bye, be undertaken by abdominal section." This view was supported by Marcy [2] and Andrews [3] who sutured the internal hernial opening discovered during laparotomy. Andrews went on to state that they were "sewing up a hole and not going through the motions of a complicated plastic procedure." At the other end of the spectrum is the emphatic statement that lateral reinforcement of the internal ring is required in every instance [4]. Which of these opposing views are correct?

In the absence of a formal study on the results of simple closure of the internal hernial opening, it is necessary to retrace the investigative steps taken thus far if this question is to be answered.

In 1977 a project was undertaken whereby patients who underwent a laparotomy for various reasons and who also suffered from a coincidental hernia had the internal hernial openings closed by means of the application of metal clips measuring $^1/_8$″ (3 mm) in width by $^5/_8$″ (15 mm) in length in the open position [5]. The number of clips applied varied from two for the smallest hernias to ten for the largest. They were placed in the peritoneum and subjacent serous tissue at intervals of approximately $^3/_8$″ (9 mm) so as to prevent the extrusion of any intra-abdominal viscus into the sac, itself left undisturbed. The results at 44 months are shown in Table 19.1. One patient was unavailable for follow-up as he died from his intra-abdominal malignancy. The follow-up of eight patients over an 8–10-year period showed no recurrences (Table 19.2).

During an operation for an intra-abdominal condition where a coincidental hernial opening exists, many surgeons close the opening by suture. Recently it was possible to question surgeons as to the details of this closure and the follow-up [6, 7]. It was clear that this

Table 19.1. Clinical details of patients (n=13; mean age, 74 years[a]) with intra-abdominal lesions and coexistent hernias. (From the *American Journal of Surgery*)

	n
Primary disease	
Colon cancer	6
Stomach cancer	1
Cholelithiasis	2
Diverticulitis	1
Intestinal obstruction	2
Right inguinal hernia	1
Type of hernia	
Indirect inguinal	7
Umbilical	2
Femoral	1
Bilateral inguinal	1
Direct inguinal	2
Results	
26–44 months postoperatively (n=11)	
Recurrence in indirect hernias	0
Direct recurrence at 9 months	1
<1 year postoperatively (n=2)	
Direct	1[b]
Indirect	1[c]

[a] Excluding one 23-year-old patient with a right inguinal hernia.
[b] Patient died at 6 months.
[c] Patient lost to follow-up.

Table 19.2. Eight- to ten-year follow-up (n=8; mean age, 70 years). [From 8]

	n
Primary pathology	
Colon cancer	3
Intestinal obstruction	2
Diverticulitis	1
Cholelithiasis	2
Type of hernia	
Indirect inguinal	5
Direct inguinal	1
Umbilical	2
Results	
Alive and well without recurrence	3
Died 6–8 years postoperatively without recurrence	5

matter had not been effectively studied in any detail. Great variations existed in the suture material used; the type of suture placement; the approximate size and location of the opening, whether direct or indirect or mixed; and the thickness of the edges of the opening. The presence of predisposing causes, for example, prostatic enlargement and the patients' ages and sex were, likewise, inaccurate. Follow-ups were mostly on the basis of impressions, but were more accurate than the operative details. One hundred surgeons were questioned. Those closing hernial openings (75) in the pediatric age group (up to 18 years of age) considered the procedure completely curative; of those closing the openings of adults (90), 75 thought the operation to be curative, eight were indefinite, and seven considered the recurrence rate to be 30%–50%.

An experimental study was undertaken in an attempt to establish whether closure of the internal opening alone was curative [8]. Fifteen beagle dogs were used in this study, and in 14 the hernia was clinically cured.

These three investigations, the clinical study of patients with hernias who undergo laparotomy, the impressions of surgeons who close hernial orifices during laparotomy, and the experimental study described above suggest that closure of the internal ring in indirect inguinal hernias is a sound therapeutic procedure, with probably no greater recurrence rate than that seen in the traditional approach.

Recent advances in technology have resulted in the replacement of major operations by ES. Indirect inguinal hernias lend themselves to such procedures and a clinical investigative study of the efficacy of this approach in such hernias has recently commenced.

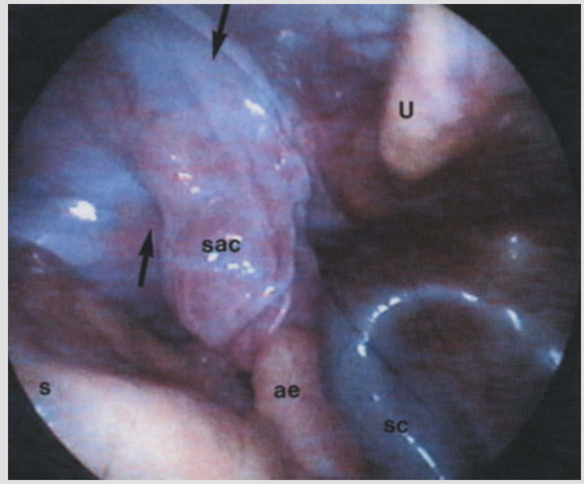

Fig. 19.1. An incarcerated appendix epiploica *(ae)* is seen bulging inside a hernial sac which has been inverted by traction on the appendix in an effort to dislodge it. *s,* Sigmoid colon; *sc,* spermatic cord; *U,* median umbilical ligament; *arrows,* upper and lower margins of hernial openings

Indications and Patient Selection

Initially, reducible indirect inguinal and femoral hernias were to form the subject of the clinical study. The differentiation of direct from indirect hernias is relatively easy in the female, in the child, in males up to the 4th decade, in those hernias in younger people which reach the scrotum, and in the elderly. It is more difficult to make an exact differentiation between a small hernia confined to the groin (bubonocele) in an adult male. It is suggested by some that radiographic investigation may assist in this differentiation [9, 10]. *Pari passu* the scope of the study has been enlarged so as to encompass direct and recurrent hernias. This may render the differential diagnosis of an inguinal hernia unnecessary as both types hernias can be treated laparoscopically. Finally, certain types of incarcerated hernias may also be managed laparoscopically (Fig. 19.1).

Preparation of Patient

Preoperative Preparation

The usual precautions for laparoscopy are carried out, namely catheters are placed in the bladder and stomach and both viscera emptied.

Anesthesia

Presently the operation is carried out under general anesthesia, but the intention is to perform the procedure under local anesthesia and sedation, as is the routine for tubal sterilization in some centers.

Patient Positioning and Draping

After induction of the pneumoperitoneum, the patient, who is lying supine, is placed in the Trendelenburg position so as to displace the intestine and expose the inguinal region. The testes are left exposed when the patient is draped. The arms are positioned so as to be at the side and the drapes cover the patient's head, as the surgeon will be placed towards the head of the table passing the operating instruments distally to the inguinal region.

Layout of Ancillary Instrumentation and Positioning of Staff

The surgeon is generally placed towards the head of the table; mostly he/she will stand on the same side as the hernia, but, at times, the shape of the ring is such that it can be stapled more easily standing on the contralateral side. In the case of bilateral hernias, it is immaterial on which side the surgeon stands as the stapler can be passed to the opposite side without difficulty.

The assistant is placed opposite the surgeon at the abdominal level, with the scrub nurse beside him/her at a more distal level.

The video monitor is placed at the foot of the table, as the surgeon faces the patient's feet. The insufflator and light source occupy a position opposite, and at the same level, as the surgeon.

Specific Instruments for Procedure

Apart from the usual instruments used in video-laparoscopy, a 12 mm trocar and cannula assembly is necessary. As it is necessary to pick up the edges of the hernial opening, approximate them, and apply a staple, a special instrument that will accomplish this and pass through a 12 mm cannula has been designed (Herniastat, Innovative Surgical Devices, Westbury, NY).

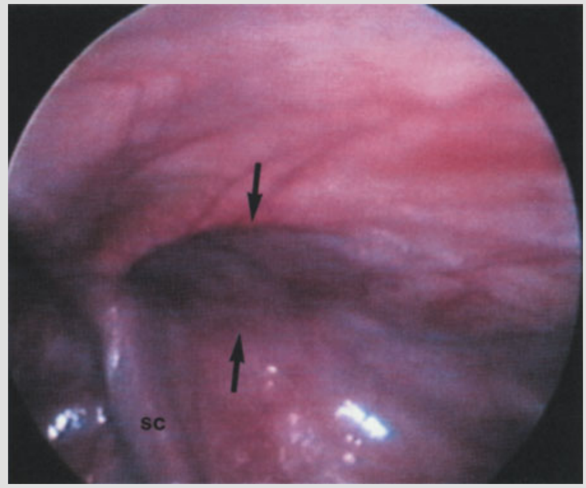

Fig. 19.2. The orifice of a left indirect inguinal hernia is seen. *Arrows*, upper and lower margins of the abdominal openings of the processus vaginalis; *sc*, spermatic cord

Operative Steps

A pneumoperitoneum is induced by the usual method. The hernial orifice is located (Fig. 19.2) by either following the usual anatomic guidelines, namely in a position lateral to the lateral umbilical fold (raised by the inferior epigastric vessels), or more simply by external pressure over the internal ring. The hernial orifice will appear larger than expected due to dilatation by the pneumoperitoneum and the laparoscopic magnification.

The Spermatic Cord

Damage to the spermatic cord must be avoided. Depending on the build of the patient, it may be possible to visualize the cord. This is easy in the thin patient, but more difficult in the obese. Assistance may be obtained by traction on the testis of the affected side when the cord will be seen to move longitudinally. In practice, if the patient is thin the cord can be seen; if obese, visualization is probably unnecessary as the cord is protected by a layer of retroperitoneal fat. Further, the staples are applied in a parallel or longitudinal direction, making it difficult to occlude cord structures. Lastly, the staples do not close completely, as in a ligating clip.

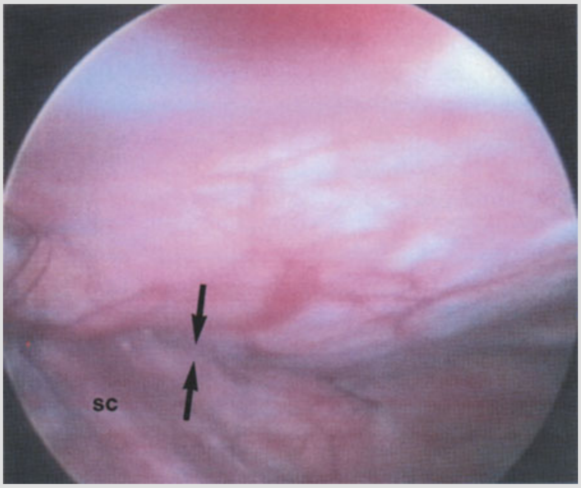

Fig. 19.3. The upper and lower margins of the case depicted in Fig. 19.2 after compression has approximated the margins; *sc*, spermatic cord

The Enlarged Internal Opening

Initially, difficulty was encountered in approximating the edges of the opening. Assistance was obtained by several maneuvers. After identifying the internal opening, reduction of the intra-abdominal pressure will diminish the size of the opening. External digital pressure over the internal ring is even more effective (Fig. 19.3); as an alternative, a compression device, such as is used following femoral artery puncture for angiography, is very useful. The purpose is to reduce the orifice to a narrow slit whose walls can be easily approximated; this is the appearance in the noninflated abdominal cavity.

Closure of the Internal Opening

A puncture with a 12 mm trocar and cannula assembly is made on the same side as the hernia lateral to the linea semilunaris, at approximately the level of the umbilicus, which ensures muscular, rather than tendinous, penetration. After withdrawing the trocar, the stapling instrument is inserted through the cannula. This instrument combines an extendible forceps which can be opened and closed, as well as a stapling mechanism containing eight stainless steel or titanium staples measuring 14 mm in length by 0.5 mm in diameter. The staple points differ from the standard staple by crossing one another. This damages the tissue sufficiently so as to require repair by fibrous tissue.

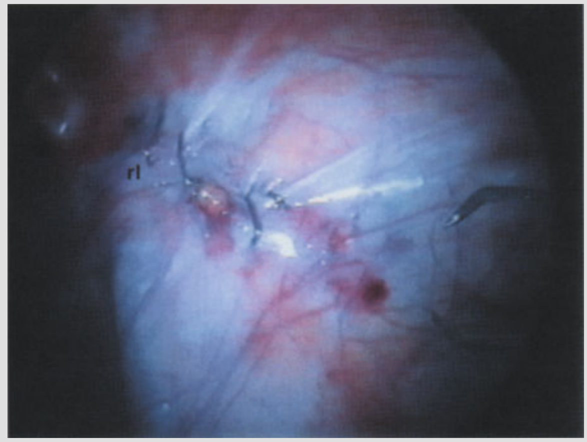

Fig. 19.4. An indirect hernia in a female patient closed by four staples; *rl*, round ligament

The opened forceps penetrate the margins of the internal hernial opening about 12 mm ($^1/_2''$) from each edge, after which the forceps are closed and retracted. The enclosed peritoneum, subperitoneal tissue, and variable amounts of transversalis fascia are approximated to the stapling device which is fired sequentially; the number of staples placed depends on the size of the orifice (Fig. 19.4).

After satisfactory closure of the opening is achieved, the Herniastat is withdrawn, the gas is evacuated, and the trocars and cannulae removed. The sheath at the umbilicus is sutured with 2/0 synthetic suture material and the skin approximated with adhesive strips.

Postoperative Care

The catheter is removed after the dressings are applied. Pain medication is administered as required and the patient discharged approximately 12 h postoperatively; if the operation is performed after noon, the patient is kept overnight. Untoward occurrences, such as excessive drowsiness, inability to micturate, nausea/vomiting require postponement of the discharge.

Results

Over the last 12 months, 21 hernial orifices have been closed – indirect inguinal hernias (seven men, three women), bilateral direct hernias (two men), recurrent inguinal hernia (one man), femoral hernia (one woman). Included in the indirect hernias are bilateral hernias (two women, one man) and two incarcerated hernias, one containing an appendix epiploica and one containing omentum. The follow-up is 2–12 months. There were no operative complications. Postoperative complications included two recurrences and one meralgia paresthetica.

Both recurrences were technical in nature. A review of the video tapes of both patients indicates that in one patient insufficient staples were placed in a large indirect inguinal hernia, and in the other patient the staples were not only insufficient, but placed in a suboptimal position, where some of them, due to malfunction of the stapler, were seen to be incompletely closed.

In the patient complaining of pain and paresthesia along the distribution of the lateral cutaneous nerve of the thigh, the etiology is unclear. This nerve lies close by the anterior superior iliac spine, a considerable distance from the most lateral staple seen in the review of the tape. A neurologic consultant was of the opinion that trauma to the nerve was possibly caused by digital pressure while palpating the surrounds of the deep inguinal ring, or by the body weight of a member of the operating team leaning on the nerve of a very thin patient, or by pressure by the restraining strap. The above would explain temporary symptoms, but the patient, when last seen some 5 months after the operation, was still symptomatic.

The role of laparoscopy in the management of femoral hernias is still unclear. While the hernial closure will prevent symptoms, one patient so treated still complains of a small swelling in the thigh, her original complaint. The various laparoscopic alternatives are still under consideration.

Comment

Since closure of the internal opening of an indirect hernia by laparoscopy was first described, similar approaches by different techniques have appeared, at first sporadically but recently in greater profusion [11–13]. These techniques are as follows:

1. Closure of the hernial orifice by continuous suture
2. Incision through the peritoneum superior to the hernial opening, blind dissection medially down the inguinal canal, placement of mesh in the space so created, and closure of the opening by the use of ligating clips
3. Eversion of the hernial sac, incision of the anterior surface of the neck of the sac, dissection of the cord to displace it inferiorly, insertion of mesh through the incision in the direction of the inguinal canal, stapling across the inverted sac, and removal of the excess sac
4. Suturing mesh across the internal opening

Whatever method is used, several requirements must be met. The internal opening must be securely closed, and there should be minimal scarring at the site of closure. Any method which leaves an area of scarring risks the adherence of loops of intestine to this site with the possibility of remote intestinal obstruction; to cure a hernia at the price of a later obstruction is unacceptable. This objection appears to apply to those methods which invert the sac into the peritoneal cavity and to those which use intraperitoneal mesh.

Those methods that employ mesh are open to all the criticisms that are associated with the implantation of foreign material. Further, in methods 2 and 3, the placement of mesh requires some dissection to create sufficient space to accommodate the material. Is it not possible that one is creating a defect that then requires repair? Finally, it is difficult to satisfactorily define the defect through an opening in the internal hernial opening.

In methods where the mesh insertion is accompanied by closure of the peritoneal opening of the hernia, it is possible that the success may be due to the latter step.

Critics of simple closure of the internal ring suggest that the stretched internal ring requires narrowing or tightening. To display this dilated ring during the traditional approach often requires the removal of a considerable amount a fat, often, erroneously, called a lipoma. This collection of fat may well serve a purpose. It is particularly well developed in the lower animals; for example, animals with intra-abdominal testes, such as occur in many rodents, pass these organs externally during the breeding season and block the internal rings with fat pads upon return of the testes [14, 15].

In the experimental study where dogs were used, it was common for the internal opening to be obscured by similar fat pads; perhaps this partly accounts for the relative infrequency of hernias in dogs as compared to humans. It is possible that the removal of the "lipoma" and other tissues to expose the internal ring creates a "wider" ring than then requires narrowing. In fact, the attractive feature of laparoscopic hernial repair is the avoidance of damage to otherwise normal structures; the standard operative procedure includes, for example, the opening of the inguinal canal, dissection of the

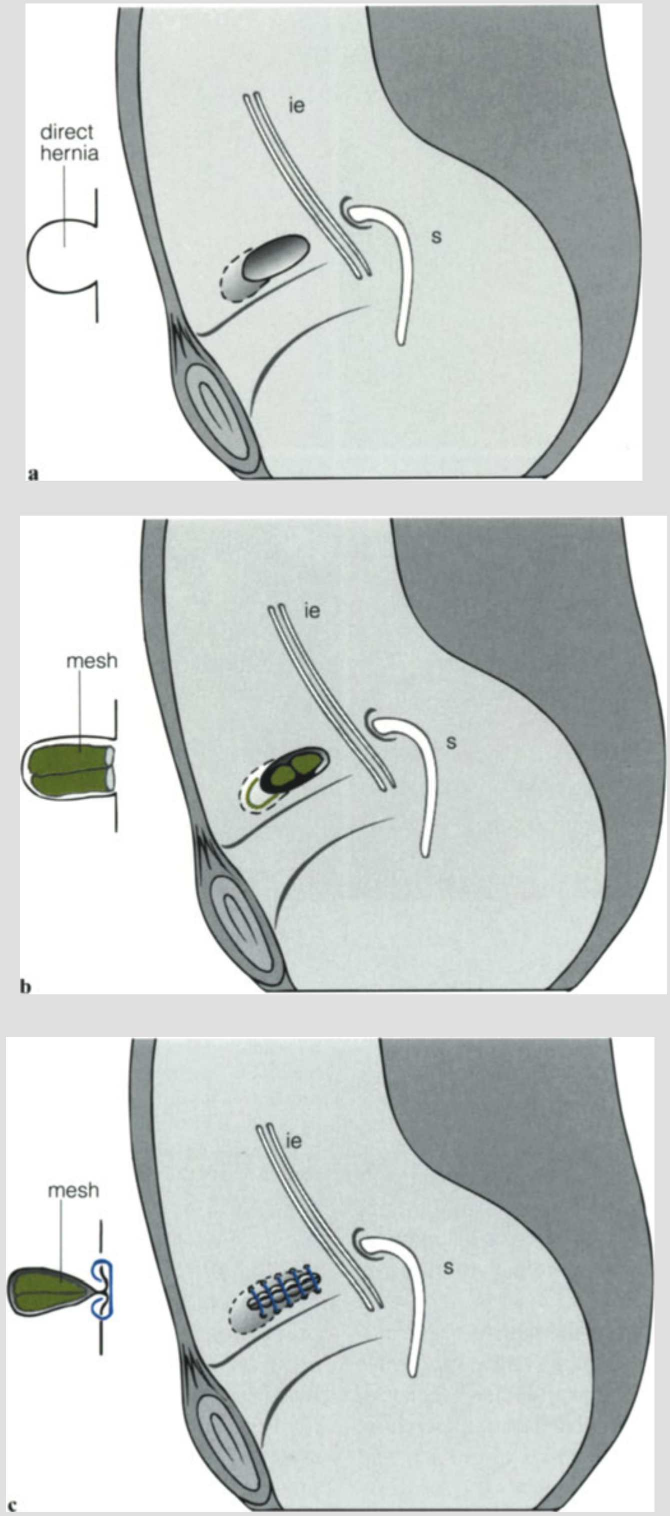

Fig. 19.5 a–c. Repair of a direct inguinal hernia by implantation of mesh and closure of overlying peritoneum. **a** Direct hernia; **b** implanted mesh; **c** stapled peritoneal closure. Right side (laparoscopic view); *ie,* inferior epigastric vessels; *s,* spermatic cord

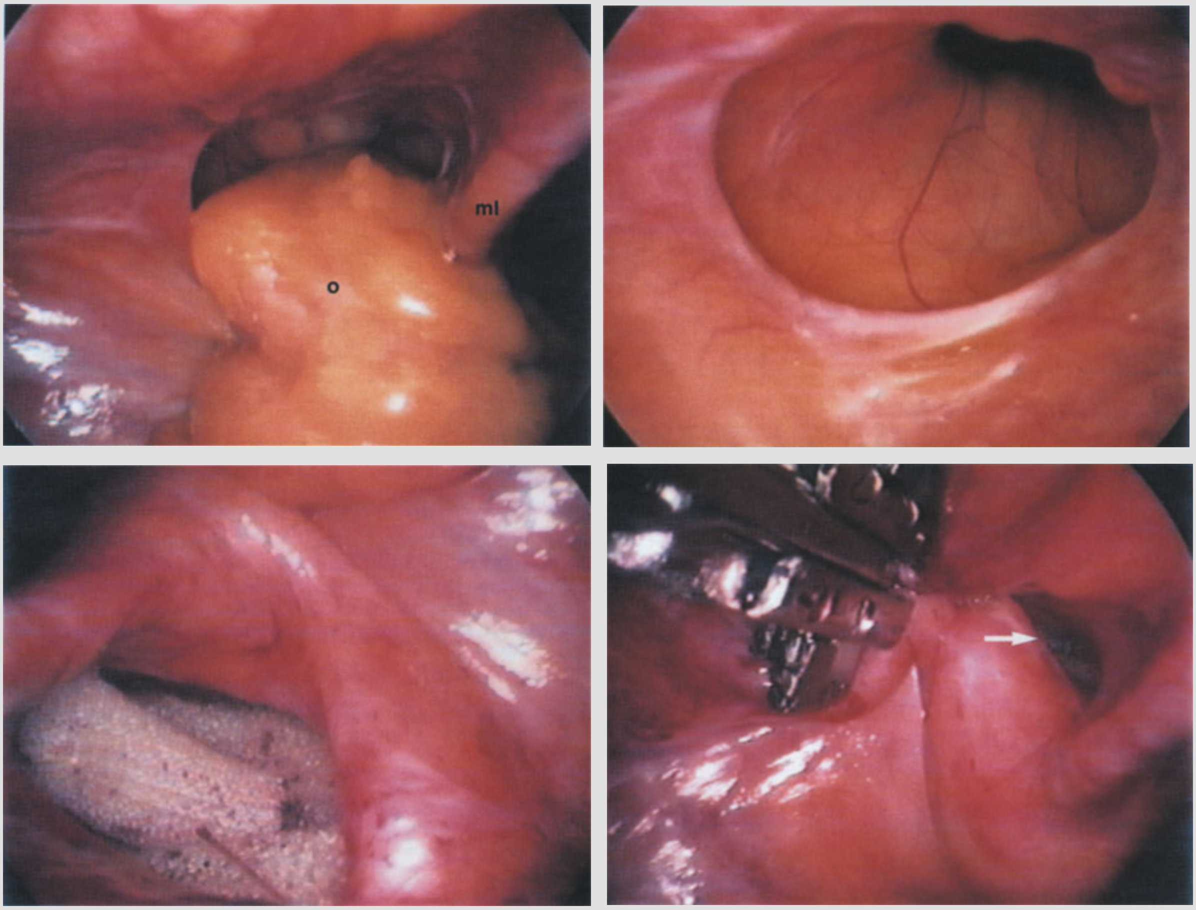

Fig. 19.6 a–d. The closure of a direct hernia as described above. **a** Incarcerated omentum being removed from a right direct hernial sac. *o,* omentum; *ml,* median umbilical ligament. **b** Right direct hernial sac. **c** Three portions of "cigarette" Marlex mesh in position. **d** The overlying peritoneum being stapled. A portion of the mesh is still visible *(arrow),* but will be covered when the medial end of the margins of the sac are stapled

spermatic cord, and destruction of the cremaster muscle.

Operations which damage or displace normal structures into abnormal positions, as in various repairs, are obviously undesirable, but acceptable, in view of the failure to find a less damaging approach. It is particularly undesirable in the inguinal canal, where humans have a conjoint muscle protective mechanism that arises and inserts much less extensively than any other primate [16].

A criticism that is levelled at the laparoscopic closure of the internal opening is that in some patients it is difficult to differentiate indirect and direct hernias. This error is unlikely to arise in all children, all women, the vast majority of hernias in males under 35, and males under 45 where the hernia reaches the scrotum. It is interesting also to note that after the age of 80 years the indirect form of hernia is more common than the direct [17]. Perhaps this differentiation is not that important now that the insertion of mesh has been shown to be successful in the treatment of direct hernias [18, 19]. Should laparoscopy demonstrate a direct hernia, repair can be carried out in one of two ways. A preperitoneal approach can be fashioned by making an incision through the peritoneum covering the direct hernia (over Hesselbach's triangle); raising flaps superiorly and inferiorly; and a roll, consisting of several layers of mesh, inserted under the flaps. The patch is secured to the peritoneum by staples, which also close the peritoneal incision. Any "indirect" component is also closed by staples. An alternative method is to place rolls of mesh in the defect and staple the approximated peritoneum over the mesh (Figs. 19.4, 19.5). The advantage of the latter technique is that a smooth, undamaged layer of peritoneum lines the abdominal wall, to which loops of intestine are unlikely to adhere. Further, avoiding an incision and dissection renders it simpler and safer.

Acknowledgement. Thanks are due to Jessica Hurwitz for preparing the diagrammatic illustrations.

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20 Laparoscopic Vagotomy

F. Dubois

Since the advent of H_2 blocking agents, the surgical treatment of uncomplicated duodenal ulcer has over the past few years assumed much less importance, but the appearance of laparoscopic surgery may perhaps lead to a recurrence in its popularity. Vagotomy and antrectomy, which is the only means of assuring regular and complete healing of the ulcer, has minor (albeit greatly exaggerated) sequelae, but at any rate for the time being is not possible via the laparoscopic route, in contrast to the various types of vagotomy. These latter procedures may be carried out endoscopically with varying degrees of ease, so that the present-day surgery of uncomplicated duodenal ulcer is once more seen in the context of vagotomy.

Laparoscopic surgery (particularly cholecystectomy) has witnessed an explosion in popularity since 1988, and since 1989 we have carried out vagotomy by this method, originally highly selective and later, in the interests of simplicity, truncal.

Anatomy

According to Delmas and Laux (1952), there exists only one peri-oesophageal plexus, corresponding to a single vagus nerve lying diffusely in the midline, which condenses into a large posterior trunk termed the abdominal vagus, all other branches being considered as collaterals.

As was pointed out by Hollender, it should be noted, that in the area of the lower oesophagus, which is where vagotomy, whether thoracic or abdominal, is performed, there exists in 90% of cases a large posterior trunk and a second anterior trunk which is readily identified. These are the trunks which are sought and divided at surgical vagotomy, the posterior being almost always single and large, while the anterior is often finer and accompanied by one or two supplementary branches.

These two trunks divide at the level of the cardia. The *anterior trunk* (Fig. 20.1) gives off the gastrohepatic branches which run in the upper part of the lesser omentum at the lower border of the left lobe of the liver and immediately divide into hepatic, biliary and pyloric branches, the latter being important for pyloric and antral motility. The gastric branches reach the anterior wall of the stomach either directly or after having formed the anterior nerve of Latarjet, which runs 1–2 cm from the lesser curve of the stomach to end as the "crow's foot" at the incisura, some 7 cm above the pylorus.

The *posterior trunk* (Fig. 20.2) gives off two types of branch:

1. A large coeliac branch which joins the right coeliac ganglion, forming, with the greater splanchnic nerve, the loop of Wrisberg. Some of its fibres may run along the hepatic and gastroduodenal arteries to reach the greater curve of the stomach: their role is probably unimportant.
2. Several gastric branches reach the back of the stomach in its vertical part. These nerves form the posterior nerve of Latarjet, which follows the course of the anterior branch, but is smaller.

This account of the anatomy explains the various types of vagotomy.

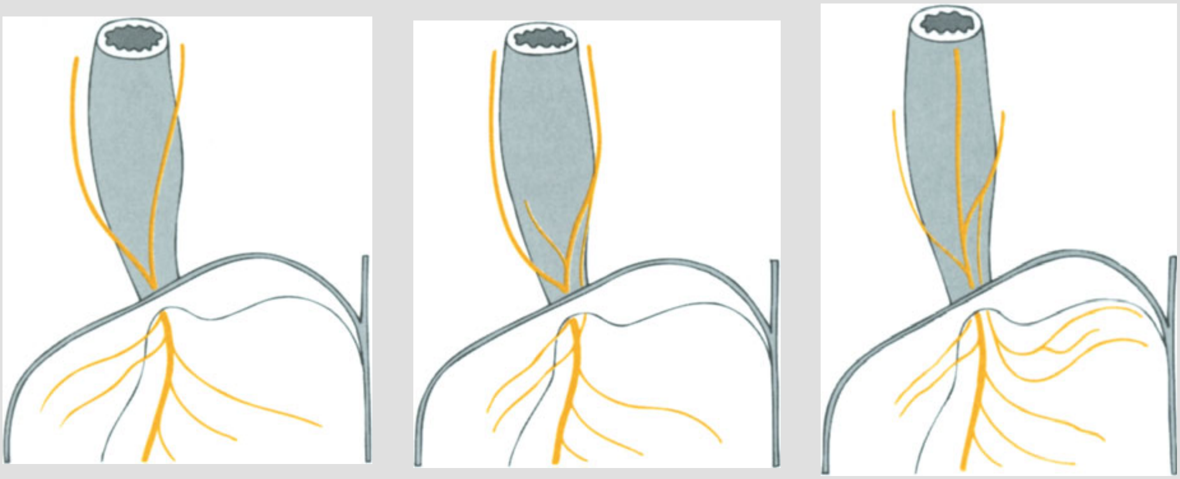
Truncul vagotomy (TV) implies section of the main trunks proximal to their division, which results in complete denervation of the stomach, pylorus, biliary tree and alimentary tract. The operation can be carried out through the lower chest or the upper abdomen.

Selective vagotomy (SV) preserves the extragastric branches, but denervates the antrum.

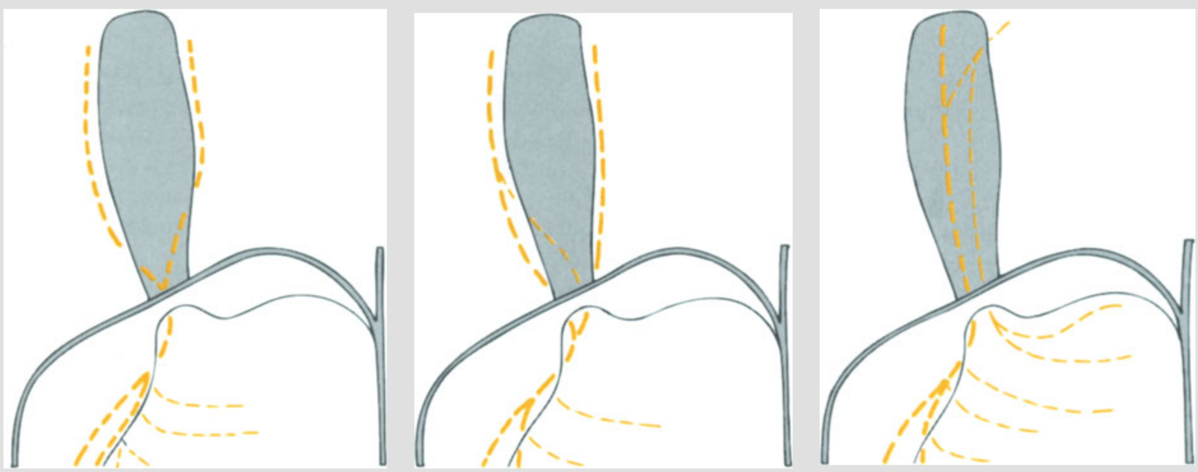
Highly selective vagotomy (or proximal gastric vagotomy, PGV) preserves the antral nerve supply by avoiding the terminal branches of the nerve of Latarjet.

There are two other anatomical features of surgical importance:

1. The gastric nerves do not anastomose within the stomach wall so that, if a small branch is overlooked, this has little physiological importance, contrary to what has been believed by some authors.
2. The nerve fibres are intimately related to the vessels, so that dividing them involves a degree of



20.1 anterior vagal nerve



20.2 posterior vagal nerve

Fig. 20.1. Anterior vagus: normal appearance. (After Hollender)

Fig. 20.2. Posterior vagus: normal appearance. (After Hollender)

devascularization of the stomach, especially in the region of the lesser curve.

Technique

The general set-up and equipment are the same as for other laparoscopic procedures. The operation must take place in a fully equipped operating theatre and must be carried out by a surgeon because of the ever-present risk of having to carry out an urgent laparotomy following unexpected findings or incidents. Ample space is required because of the size of the equipment.

General anaesthesia is necessary due to the length of the procedure and the required distension of the peritoneum, particularly around the dome of the diaphragm. The level of anaesthesia must be deep, as any unexpected restlessness may cause one of the intraperitoneal instruments to damage a viscus.

The patient lies at the centre of the operative area, with some 30° of head-up tilt, which, especially in the obese subject, serves to elevate the mesocolon. The surgeon positions him/herself between the patient's legs, thus facing the operative field, with an assistant on either side.

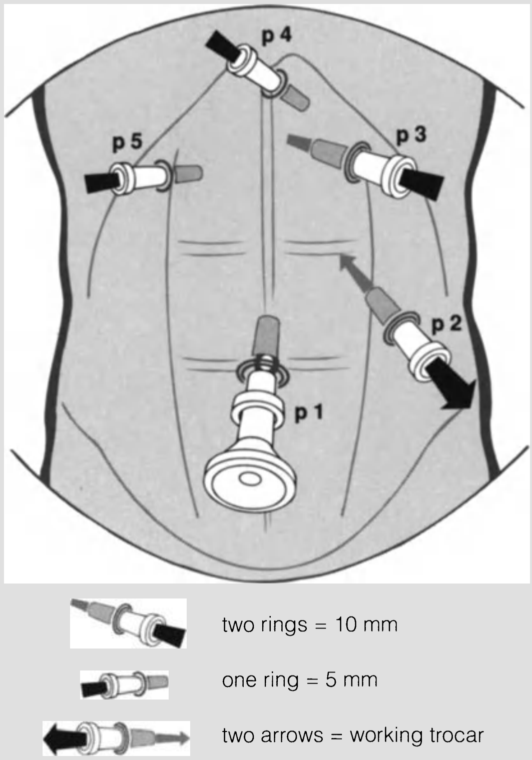


Fig. 20.3. Positioning the cannulae. *p1*, 10 mm cannula in the umbilicus for the light source; *p2*, 10 mm cannula in the left flank for the operative instruments; *p3*, 10 mm cannula under the left costal margin for the Babcock forceps; *p4*, 5 mm cannula in the left epigastrium for suction/irrigation; *p5*, 5 mm cannula under the right costal margin for use as a retractor

The stomach is emptied by a nasogastric tube, and a pneumoperitoneum is then induced through a puncture to the right of the umbilicus, or at any other suitable point as indicated by the ultrasound scan (Jakimowicz) if the presence of adhesions is suspected because of previous surgery or infection. Then the procedure is carried out under a CO_2 pressure of 14 mmHg.

The cannulae are positioned in the same way regardless of the type of vagotomy (Fig. 20.3). In the normal subject, the lens system is introduced to the right of the umbilicus via a 10 mm trocar, using a Z-shaped track in order to avoid creating a defect (Semm) (p1). The first stage in the operation consists in a thorough exploration of the entire peritoneal cavity. It is hardly ever possible to visualize the region of the duodenal ulcer, due in part to the surrounding adhesions which should not be disturbed, and in part to the difficulty of palpating the duodenum: it is therefore necessary to rely on the preoperative investigations.

A direct forward-viewing lens system is used, but it is useful also to have at hand a 30° lens, especially in a patient with a long epigastrium, in which case the telescope should be inserted at a higher level, above the umbilicus and slightly to the left, in order to avoid the falciform ligament.

If laparoscopic surgery appears feasible, then the other cannulae are introduced in the following manner:

1. One 5-mm trocar is placed beneath the right costal margin to act as an irrigation/aspiration channel and also to lift up the left lobe of the liver and the falciform ligament. The exact placing of this trocar will depend on the size and position of the falciform ligament (p5).
2. A 10-mm trocar is inserted in the nipple line below the left costal margin in order to accommodate the Babcock forceps used to manipulate the stomach and oesophagus (p3).
3. A 10-mm trocar is inserted in the left flank for the operative instruments (p2).
4. A 5-mm trocar is placed to the left of the xyphoid process to hold a retractor or forceps (p4).

The position of the various cannulae will vary according to the practice of the operator, and to whether he/she is right- or left-handed (this type of surgery in the right hypochondrium is slightly easier for the left-handed). It will also depend on the configuration of the falciform ligament, which will have been ascertained at the preliminary laparoscopic inspection. Two principles should be constantly borne in mind: first, to keep the cannulae as far apart as possible so as to avoid the "knitting needle" effect; and secondly, to take care not to approach the organs from too oblique an angle. Finally, under direct vision, the nasogastric tube is replaced by a large-bore rigid stomach tube which aids in the identification of the lesser curve. The next steps depend on the type of vagotomy to be undertaken.

Highly Selective Vagotomy – Proximal Gastric Vagotomy

Historically, PGV was the first vagotomy to be performed through the laparoscope. In 1989 (wrongly, in our view) it practically replaced other forms of surgery in the treatment of uncomplicated duodenal ulcer.

The lesser curve of the stomach and the anterior nerve of Latarjet are exposed by displacing the left lobe of the liver with the retractor held in the left hand, and drawing the stomach downwards and to the left with a Babcock forceps held in the right hand and later passed to an assistant.

The first step in the operation is to divide all the vascular pedicles along the front of the lesser curve. Using scissors, a diathermy hook and a clip applicator, the three or four pedicles which lie above the crow's foot are progressively sectioned (Fig. 20.4). It is important to leave enough stump to prevent slippage of the clip. It is equally possible to control the pedicles with bipolar diathermy before dividing them in order to avoid damage to the nerve. All these steps should be carried out gently and carefully so as to obviate bleeding and haematoma formation, which are difficult to control and slow up the operation (Fig. 20.5).

The posterior layer is dealt with in the same way. One starts by baring the mid-portion of the lesser curve of all of its small neurovascular bundles, coagulating them before division. The lesser curve is then seized with the Babcock forceps while the retractor in the left hand gently draws aside the nerve of Latarjet to expose the posterior neurovascular plane. This plane is now breached with the hook between two vascular pedicles so as to enter the lesser sac, and the gap thus created is held open so that, with the aid of the Babcock forceps, the whole gastric wall can be drawn to the right. This move may be made easier by opening the lesser omentum and identifying the posterior wall of the stomach by means of a forceps passed through it and held in the left hand. As it is progressively drawn up, the lesser curve is gradually released and the posterior vascular plane divided in the same way (Fig. 20.6). Once the lesser sac is fully opened, the posterior vascular pedicles may be divided as previously, and with the same degree of caution, up to the cardia. It only remains to dissect out the gastro-oesophageal junction

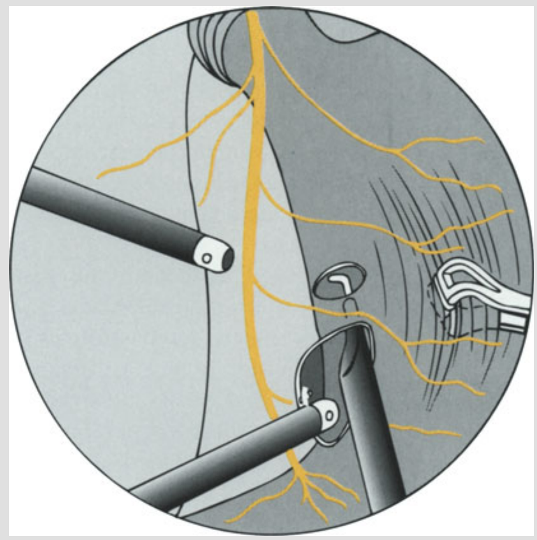


Fig. 20.5. Highly selective vagotomy: first stage. The retractor and the Babcock forceps put the anterior layer on the stretch, while the hook isolates the second vascular pedicle

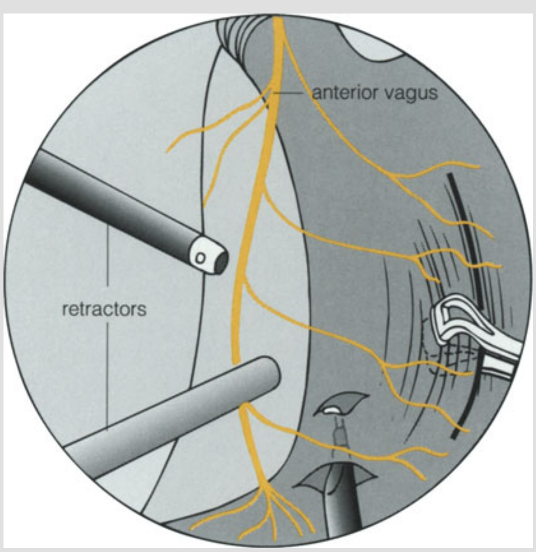


Fig. 20.4. Highly selective vagotomy: first stage. The hook isolates the first neurovascular pedicle, proximal to the pes anserinus

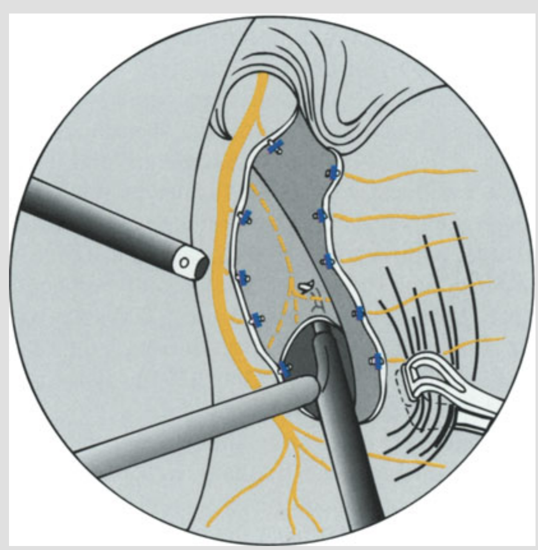


Fig. 20.6. Highly selective vagotomy: second stage. A retractor placed in the defect in the posterior layer allows the hook to isolate the posterior pedicles

which, as described above, is drawn alternatively forwards and backwards as mobilization proceeds.

Anteriorly, the retractor which has been passed through the flaccid portion of the lesser omentum pulls it upwards, while the Babcock forceps elevates the front wall of the stomach. The anterior aspect of the cardia is, as a rule, concealed by a thick neurovascular pedicle which needs to be freed, controlled and divided. Dissection proceeds upwards and to the left towards the angle of His, freeing the last 2 cm of the oesophagus.

Dissection of the posterior aspect of the cardia and oesophagus requires the neurovascular structures to be put on the stretch by drawing the stomach upwards and to the left, while leaving the lesser omentum to the right. All tense structures are coagulated and divided up to the left nerve of Grassi.

Following this prolonged dissection, the gastric tube is withdrawn and the whole oesophagus seized with the Babcock forceps so as to demonstrate its posterior aspect and allow division of any last remaining fibres.

Attention is now turned to the lower part of the dissection to ensure that there is no bleeding and that denervation has been complete except for the terminal branches. Certain authors, in view of the high late recurrence rate following PGV, extend the denervation lower down on the lesser curve, cutting one or more of the distal branches, but stopping 2 cm short of the pylorus.

The PGV is now complete, but mobilization of the oesophagus has created a risk of gastro-oesophageal reflux which requires correction. The easiest means of accomplishing this is to refashion the angle of His, but in our view this is insufficient.

The most simple additional procedure is to devise an anterior (Dor) valve by attaching the fundus to the anterior aspect of the bared oesophagus and then to the cardia. Because of the difficulty of tying knots through the laparoscope, we prefer to use a continuous suture of three to four bites, controlled at each end by a clip, which should not be too tightly applied for fear of cutting the thread. We use a 000 absorbable stitch on a $^3/_8$ curved needle, introduced via the 10 mm cannula in the left flank. Only 10–15 cm thread is needed to insert the suture.

It is better, but much more difficult, especially in the absence of the proper instruments, to construct a posterior valve. With the oesophagus mobilized, a forceps is introduced behind it from the right-hand side so as to emerge at the angle of His and catch the front of the fundus. The stomach is then drawn over to the right and, as soon as it appears to the right of the oesophagus, it is picked up with a Babcock forceps and wrapped over the front of the oesophagus. Two sutures (tied and clipped as already described) attach the back of the valve to the right crus of the diaphragm (the so-called Toupet procedure). For extra strength, the edge of the valve may be fixed with one or two sutures to the right side of the oesophagus. Once again, these manoeuvres, which are so simple in an open operation, are difficult and tedious via the laparoscope, given presently available equipment.

The operation is completed by a final inspection of the field, copious lavage with saline, infiltration of 0.5% bupivacaine and careful aspiration of the pneumoperitoneum. No drainage is required.

Bilateral Truncal Vagotomy

The operative set-up is as already described. Truncal vagotomy is much easier to carry out than PGV. The posterior vagus is the first to be divided (Fig. 20.7). The pars flaccida of the lesser omentum is breached, two forceps or retractors introduced through it and the defect progressively enlarged towards the oesophagus. A left hepatic artery of varying size is usually found and is divided between clips.

The oesophagus is then caught in a Babcock forceps, while the right crus of the diaphragm is pushed downwards by the retractor. The tense fold of peritoneum between the two structures is now opened with scissors or a hook and the back of the oesophagus freed.

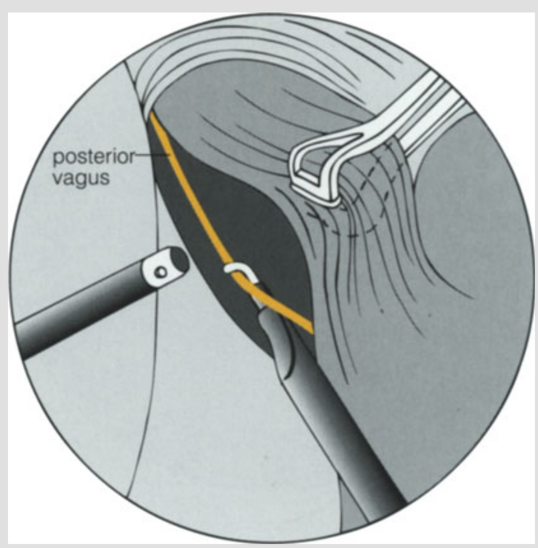


Fig. 20.7. Truncal vagotomy: division of the posterior vagus

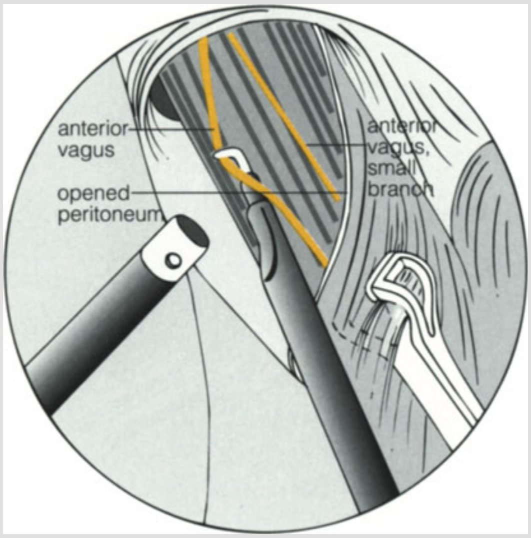


Fig. 20.8. Truncal vagotomy: division of the anterior vagus

It is usually quite easy to find the posterior trunk and to free it over 1–2 cm with the aid of a hook (Fig. 20.7). It is then coagulated and cut. Although this trunk is usually single and bulky, it is important to explore the back of the oesophagus and the front of the crus to exclude the presence of other small fibres and to divide any which are found.

Section of the anterior trunk (Fig. 20.8) begins by incising the peritoneum at the hiatus. The whole oesophagus is drawn down by the Babcock forceps so as to put the peritoneum on the stretch, open out the hiatus and elongate the abdominal oesophagus. The anterior aspect is now freed, and the anterior nerve trunk (which is usually finer than the posterior) identified, coagulated and divided. One or more accessory fibres are frequently present and must also be sectioned.

In contrast to the posterior trunk, the fibres of the anterior vagus often adhere to the muscle and care must be taken not to damage the oesophagus in freeing them. The vessels which run in front of the oesophagus must also be spared as injury to them may lead to bleeding or haematoma which may be difficult to control.

In truncal vagotomy, the oesophagus is only partially mobilized and the angle of His is preserved so that it is not necessary to devise an antireflux mechanism, which greatly simplifies the operation. However, if the oesophagus has been widely mobilized in a prolonged search for the nerves, reflux must be prevented as described above.

Selective Vagotomy

The selective operation precedes PGV, but has now been replaced by it. It consists in dividing all nerves to the stomach except the posterior trunk and the hepatic and pyloric branches. It is necessary to divide the coronary vessels and to bare the cardia and lower oesophagus. Although in theory this is achievable via the laparoscope, it has never, to our knowledge, been performed laparoscopically.

Mixed Forms of Vagotomy

Because of the length and complexity of laparoscopic PGV, combined procedures are more often used, the principle being to combine a posterior truncal vagotomy (which is easy to carry out) with division of some of the anterior gastric nerves, which is the least difficult aspect of PGV.

Division of the posterior trunk has already been described. The anterior trunks may be divided by one of two methods: Hill and Barker (1984) described a technique for the first stage of PGV which takes less than one-third of the time required for a full PGV and at the same time does not open the hiatus so that an antireflux procedure is not necessary. Taylor described an anterior seromyotomy which has been carried out endoscopically by Mouiel, who has outlined the technique elsewhere.

Thoracoscopic Truncal Vagotomy

Description of this technique seems appropriate as, although it does not involve laparoscopy, the equipment and methods are the same. For many years Wittmoser (personal communication) carried out thoracoscopic neurectomies, vagotomy in particular, recommending two separate procedures separated by an interval of 3 weeks and combined with bilateral splanchnicectomy in order to obviate spasm of the pylorus.

We prefer a unilateral (usually left-sided unless there are pleural adhesions) approach, for bilateral truncal vagotomy. Under general anaesthesia, a Carlens tube is passed so as to collapse the lung on the side to be explored. As for a posterolateral thoracotomy, the patient lies on his/her side with the surgeon standing behind. To induce the pneumothorax a small incision is made through the 7th or 8th interspace in the posterior axillary line and a blunt forceps passed through the muscles. The characteristic sound of air entry signals that the pleura has been opened, and the

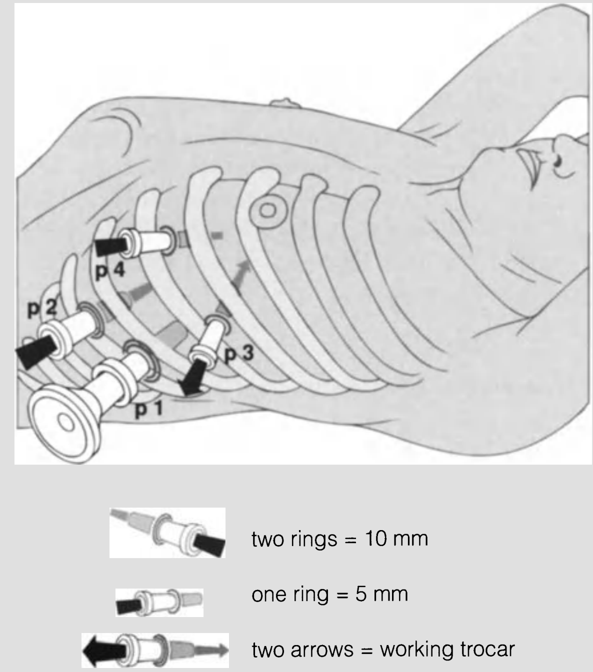


Fig. 20.9. Thoracoscopic vagotomy: placing the cannulae. *p1*, 10 mm cannula in the 8th interspace in the posterior axillary line for the light source; *p2*, 10 mm cannula in the mid-axillary line for the Babcock forceps; *p3*, 5 mm cannula in the 6th interspace in the mid-axillary line for the hook; *p4*, additional 5 mm cannula in the anterior axillary line for possible introduction of a retractor

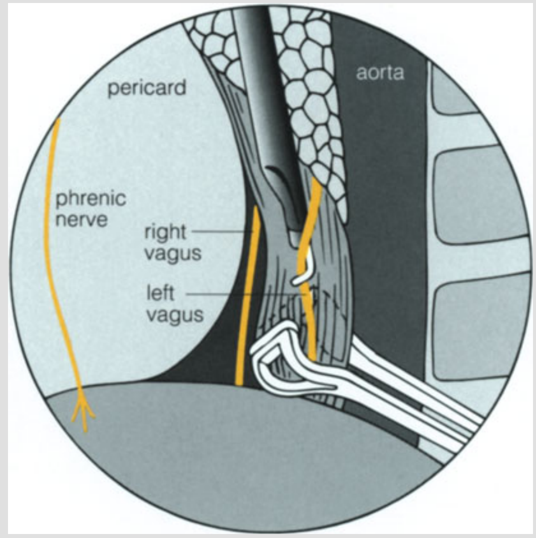


Fig. 20.10. Truncal vagotomy via left thoracoscopy: operative view

orifice is then enlarged by introducing a 10 mm trocar through which the lighted telescope is passed (p1). The collapsed lung retracts, and low-pressure CO_2 insufflation is maintained so as to eliminate the (theoretical) risk of air embolus.

General inspection of the pleural cavity will identify any adhesions and allow a point to be chosen for the insertion of additional cannulae (Fig. 20.9). Normally, two 5 mm trocars are needed, placed as far as possible apart in the mid-axillary line. The suction/irrigation channel, held in the left hand, serves as a retractor. The scissors and diathermy hook are introduced via the upper cannula and held in the right hand (in the case of a left-handed operator the instrumentation is reversed) (p3). It is sometimes necessary to introduce a fourth 5 mm cannula in the anterior axillary line and to replace the lower one by a 10 mm instrument to carry a Babcock forceps or clip applicator.

The operation begins by dividing any adhesions which hamper access to the oesophageal hiatus. The pleura is incised in front of the aorta, and the oesophagus freed with the retractor and the hook. Usually, one left anterior nerve trunk, or two trunks which unite lower down, are seen and these are coagulated and divided. The front and back of the oesophagus and then its right edge are dissected out, and any nerve trunk encountered is divided as before. Often, there is one right-sided nerve which remains attached to the pleura from which it must be freed. The oesophagus must sometimes be caught in the Babcock forceps in order to dissect its right border (Fig. 20.10).

There is seldom much bleeding as the peri-oesophageal space in this area is avascular though, as there is no gaseous compression (unlike laparoscopy), a certain degree of oozing from small veins is usual, though not as a rule troublesome. If the right pleural space should be breached, it is of no great importance as the defect will be sealed by the pressure in the right lung maintained by the anaesthetist and by the oesophagus itself when it returns to its normal position. A drain is required only if there is persistent oozing or an air leak and it should be removed as soon as leakage ceases. Postoperative pain is lessened by infiltration of the intercostal spaces with local anaesthetic.

Problems Common to All Types of Vagotomy

Postoperative Measures

These are minimal following laparoscopy:

1. A cephalosporin, together with heparin, is given by injection with the premedication. Anticoagulation is continued during the hospital stay.
2. A nasogastric tube is left in place for 24 h to prevent possible acute dilatation of the stomach and to allow estimation of gastric acidity, which is a measure of completeness of the vagotomy.
3. Oral fluids are permitted as soon as the tube is removed and alimentation progressively restored in line with bowel function.
4. The postoperative course is usually surprisingly uneventful.

Intraoperative Problems

Only those intraoperative problems which are specific to vagotomy will be mentioned:

1. The most frequent is that of bleeding during dissection of the vascular pedicles along the lesser curve of the stomach. This is difficult to control and may endanger the nerve of Latarjet, so that ligation or coagulation of large bundles must be avoided. The same problem arises when a vessel retracts and forms a haematoma in the omentum.
2. The oesophagus may be damaged during the dissection. In case of doubt, an injection of air or coloured material down the tube may clarify the situation. Such defects can usually be closed by a suture supplemented by application of the gastric fundus.
3. Clearly, if the bleeding or visceral injury cannot be controlled with complete certainty, a formal laparotomy is mandatory.

Associated Procedures

Other pathology, either known of beforehand or discovered at the time, may require attention. This could take the form of freeing of adhesions, cholecystectomy, deroofing of a biliary cyst, liver biopsy, or, if absolutely necessary, appendicectomy or open operation.

More specifically, pylorospasm, either pre-existing or occurring at operation, may indicate the need for endoscopic dilatation. This can be carried out in two ways, namely by passage of a balloon down the operating channel of a fibrescope (Microvasive Rigiflex TTS 55 22 18 mm size) or, if a greater degree of dilatation is required, by passing a guide wire through the pylorus over which a balloon (Microvasive Rigiflex OTW 5135 30 mm size) is threaded.

Results

The indications and the results of vagotomy have been extensively studied and will not be repeated here. On the other hand, experience of laparoscopic vagotomy extends over scarcely more than 1 year, and all series are very small. This is in the context of a condition whose treatment can only be evaluated after many years. Firm views are therefore premature, but there seems no reason why the route of access should influence long-term results so that the relevant question is the quality of the vagotomy. At the present time one can safely say that:

1. The postoperative course is very smooth, and we have heard no report of serious complications from others practising this type of surgery.
2. PGV is possible via the laparoscope, but is a lengthy and delicate procedure. In contrast, a combination of posterior truncal vagotomy with anterior selective denervation, either by nerve section as in PGV or by seromyotomy, is much easier and quicker and is the method of choice for those who dislike total vagotomy.
3. Bilateral truncal vagotomy is, in contrast, easily carried out via the laparoscope or, as we prefer, through the pleura. The efficacy of this procedure is proven, and some surgeons, disappointed by the high incidence of late recurrence following PGV, carry the denervation further down towards the pylorus, thus achieving an almost complete vagotomy.
4. There undoubtedly exists a risk of postoperative gastric stasis, due either to pylorospasm or atony of the stomach, which was evaluated by Dragstedt (1947) at 40%. However, the true figure probably lies closer to 10%, as witnessed by the rare need for secondary pyloroplasty following oesophagectomy. We originally thought that routine dilatation of the pylorus was required following total vagotomy, but it seems that this can safely be omitted and reserved as a secondary procedure if gastric stasis persists.

Conclusion

Vagotomy of various types can be carried out via the laparoscopic approach, under the same conditions as apply to other forms of endoscopic surgery. The typically benign postoperative course and the short period of inactivity compare favourably with prolonged medical treatment. It is too early to assess the results, but there seems no reason why these should differ from those of vagotomy carried out by open surgery.

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21 Laparoscopic Posterior Truncal Vagotomy and Anterior Seromyotomy

J. Mouiel and N. Katkhouda

Introduction

Posterior truncal vagotomy and anterior seromyotomy as described by Taylor for the elective treatment of chronic duodenal ulcer is the operation of choice, more simple, and expedient than other techniques of vagotomy, as well being equally effective and safe. According to our experience in conventional open surgery, we have performed this procedure under laparoscopy regularly since 1989 with the same early results.

The *principles* of the operation are based on the anatomical studies of Latarjet who showed that the secretory nerves, originating from the anterior and posterior gastric nerves, course through the superficial seromuscular layer of the stomach before penetrating the gastric wall beyond the vascular pedicles. Division of the seromuscular layer only, sparing the inner mucosa, interrupts the secretory branches of the vagus nerves (Fig. 21.1). It has been established experimentally that, to be efficacious, seromyotomy should be performed at precisely 1.5 cm from and parallel to the lesser curvature. In his original technique described in 1979, Taylor advocated the incision of the seromuscular layer of the anterior and posterior aspects of the stomach beginning at the incisura cardiaca and coursing to the incisura angularis which, in reality, corresponds to fundic denervation. In 1982, this same author proposed replacing the posterior seromyotomy by posterior truncal vagotomy as Hill and Barker had already advocated in 1978 for highly selective vagotomy. Complete division of the posterior vagus nerve ensures total denervation of the posterior parasympathetic territory without creating any adverse secondary effects on the pancreas or the digestive tract as shown by Smith and Burge. This means that there is no secondary postoperative diarrhea and that antropyloric motility is preserved.

Indeed, as anterior seromyotomy preserves the antropyloric branches of Latarjet's nerve, adequate motility of the antropyloric pump is maintained while precluding pyloric spasm. Moreover, this ensures normal physiological emptying of the stomach and obviates the need for associated drainage procedures (Fig. 21.2). Experimentally, Daniel had shown that preservation of the antropyloric branches of Latarjet's nerve in the dog ensured adequate gastric emptying through vagovagal arcs.

Indications and Patient Selection

In general, preoperative evaluation of patients with chronic duodenal ulcer disease is similar to that for laparoscopic cholecystectomy with the same absolute and relative contraindications. In the elective setting, surgical intervention for duodenal ulcer disease is indicated in:

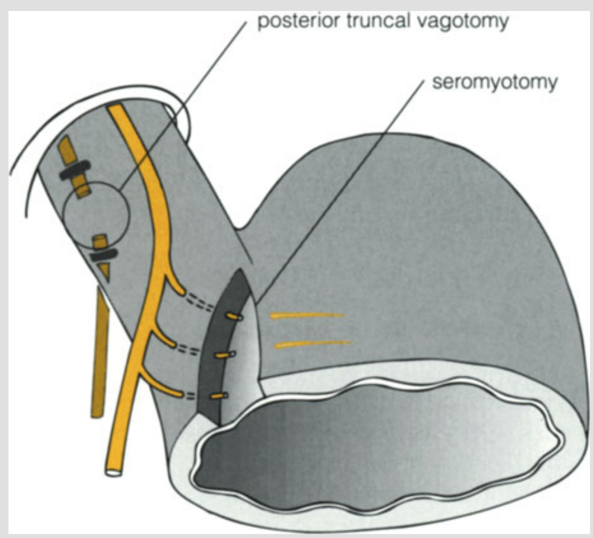

Fig. 21.1. Principle of Taylor's procedure: the posterior truncal vagotomy ensures the denervation of the posterior cellular mass. The anterior seromyotomy ensures the selective denervation of the anterior cellular mass. The anterior seromyotomy ensures the selective denervation of the fundus by division of the secretory nerves originating from the anterior nerve of Latarjet. Note the subserosal disposition of these nerves before they penetrate obliquely into the gastric wall

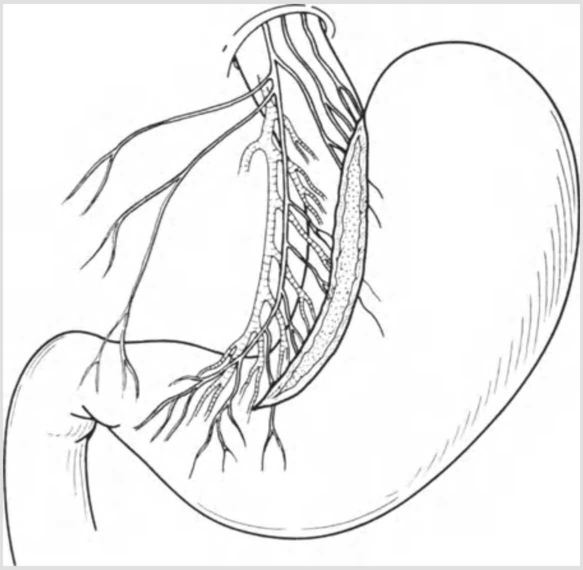

Fig. 21.2. Anterior seromyotomy begins at the esophagogastric junction, courses parallel to the lesser curvature at 1.5 cm from its border and stops at the "crow's foot," preserving the two last branches

1. Patients in whom the disease is resistant to medical treatment in spite of perfect compliance to medical advice for at least 2 years.
2. Patients followed clinically and endoscopically with regular and well-conducted endoscopic and clinical control examinations.
3. Patients without intercurrent complications.

Surgery is recommended as well for patients who cannot be followed regularly because of geographical or socioeconomic reasons.

Preoperative Preparation

As in elective open surgery, preoperative work-up includes evaluation of general status, risk factors, as well as the ulcer disease which implies endoscopic and secretory investigations. Endoscopy documents the ulcer which is usually linear without associated stenosis or haemorrhagic signs. Secretory tests include complete acidity evaluation with measurement of unstimulated, basal acid output (BAO), and peak acid output (PAO) after stimulation with pentagastrin. These tests are necessary to evaluate the degree of hyperacidity in patients who are intractable to medical treatment. These tests are also useful to demonstrate postoperative reduction of acid output. According to the clinical features of the disease, a serum gastrin level should be obtained to exclude a gastrinoma.

Surgical Procedure

As in traditional open surgery, general anesthesia and endotracheal intubation are used. The creation and continuation of pneumoperitoneum, the techniques of aspiration-lavage, thermocautery, and laser are the same as for other forms of laparoscopic surgery and are described in other chapters of this book. We will mention herein only the problems which are specific to laparoscopic vagotomy and which concern the positioning of the patient, instrumentation, approaches, exploration, and hemostatic techniques.

Patient Positioning

The patient is positioned in much the same way as for open cholecystectomy: the trunk is elevated 15°, lateral (left or right) tilting (also 15°) of the patient should be possible; a pillow roll or a bolster (10 cm) should be available. The patient is placed in the supine position, legs spread apart as in a two-team approach. The operating surgeon stands between the legs of the patient, the room nurse and first assistant are on the left, the second assistant on the right. The video-endoscopic system with irrigation/suction is placed on the left, and a second monitor with the laser unit is placed on the right. Electrocautery (Valleylab) and YAG laser systems (Microcontrol) complete the operating room units.

The patient is prepared and draped, and the instruments are laid out as in traditional gastric surgery because an open operation may be required whenever laparoscopic surgery is deemed impossible or hazardous.

Instrumentation

In addition to the instruments usually utilized for this type of surgery, we recommend:

1. An angulated hook coagulator/dissector with a canal for evacuation of smoke (Storz)
2. Clip forceps (simple: Ligaclip, or multiple: Endoclip)
3. Two Semm needle holders (Storz)

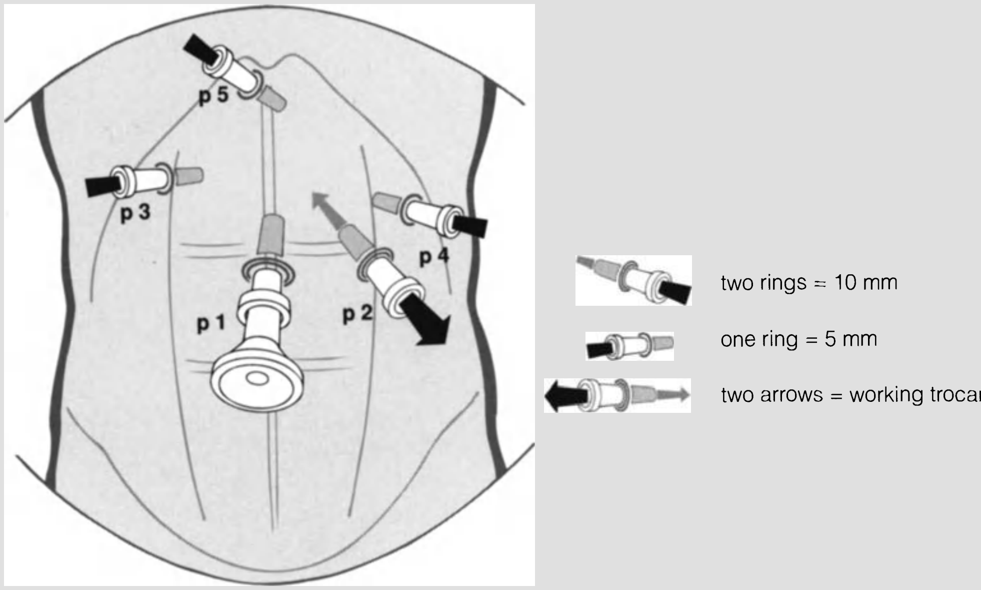

Fig. 21.3. Approaches. *p1* Video-laparoscopic trocar port (11 mm); *p2*, operating port (11 mm); *p3* right grasping forceps port (5 mm); *p4* left grasping forceps port (5 mm); *p5*, palpation or irrigation/suction trocar port (5 mm)

4. Absorbable monofilament sutures with 2-cm straight needles (Davis-Geck, Ethicon)
5. Endoloops with preformed Roeder knot (Ethibinder)
6. Application systems for laser coagulation and division and collagen spray (Storz)

Surgical Approaches

Once the pneumoperitoneum has been created, the first trocar to be inserted is the video-laparoscopic 11-mm port introduced at one-third of the distance between the umbilicus and the xiphoid process (p1). Three further 5-mm and one 11-mm trocars are then inserted under visual control as shown in Fig. 21.3.

These approaches are closed at the end of the operation by running intradermic sutures after complete desufflation of the abdomen and infiltration of the skin margins with local anesthesia in an effort to reduce postoperative pain.

Exploration

The abdominal cavity is explored as soon as the video laparoscope is inserted. The surgeon should be sure that the operation is feasible without any major problems and particularly that the liver can be retracted so that the operative area is visible. Associated lesions amenable to laparoscopic surgery are noted (adhesions, appendicitis, cholecystitis, biliary cyst). If the operation is impossible or seems dangerous or difficult, open surgery will of course be preferred. The patient should be informed of this possibility beforehand.

Hemostasis Procedures

Several procedures are available:

1. The hook coagulator is used with monopolar current to coagulate small-caliber vessels safely.
2. The Nd-YAG: laser coagulates superficial surfaces by contact fiber.
3. Titanium clips are used for the short gastric, left gastric, and small hepatic vessels which must be skeletonized first.
4. Suture ligation with a 4/0 monofilament, 15 cm long, ensures hemostasis as in open surgery.

All types of knots (flat, double, Roeder) may be made. The endoloop is required only exceptionally in this

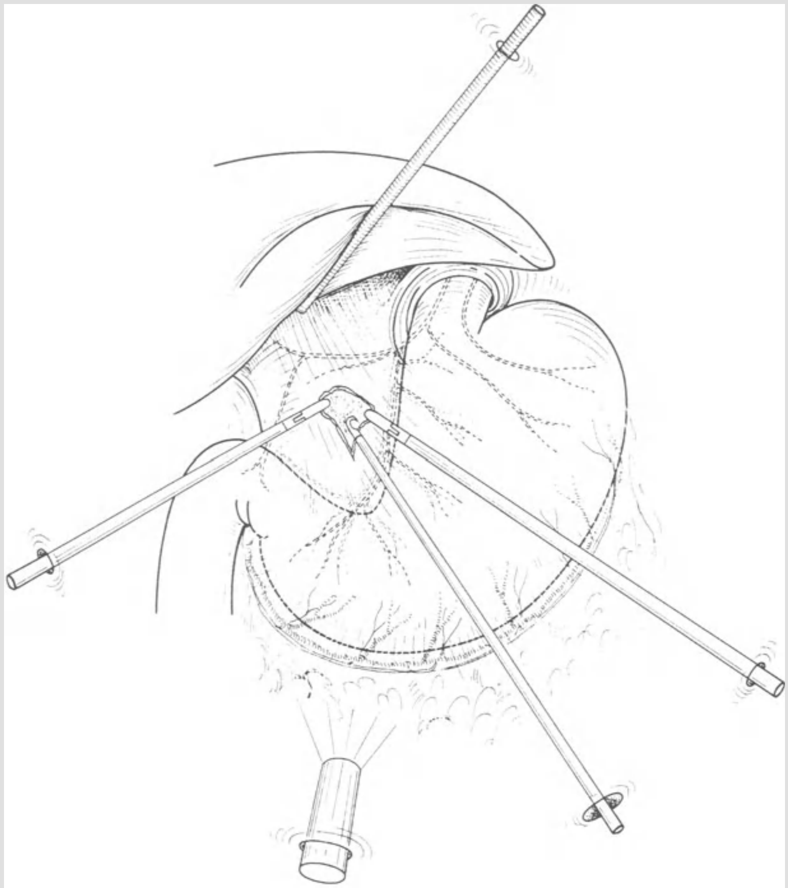

Fig. 21.4. Access to the hiatal area: opening of the pars flaccida

operation. Running sutures may also be employed: the suture may be stopped with a knot secured by a clip, and collagen is spread on top to complete the closure.

Technique of Posterior Truncal Vagotomy and Anterior Seromyotomy

The procedure consists of three steps: approach to the hiatal area, posterior vagotomy, anterior vagotomy.

Approach to the Hiatal Area

The left lobe of the liver is retracted with the xiphoid probe. The lesser sac is entered through an opening in the pars flaccida held between two angulated graspers which present the areolar tissues to the hook coagulator/dissector (Fig. 21.4). Dissection is continued until the fleshy portion of the right crus is reached (Figs. 21.5, 21.6). If a left gastric vein or an accessory left hepatic artery is encountered, they may be divided between two clips as necessary.

Posterior Truncal Vagotomy

The two major landmarks for posterior truncal vagotomy are the caudate lobe and the right crus (Fig. 21.7) which can be grasped by the right-side grasping forceps and held to the right while the coagulator/dissector hook opens the pre-esophageal peritoneum. The abdominal esophagus is retracted to the left allowing visualization of the areolar tissue where the posterior vagus nerve, easily recognized by its white color, can then be identified. While gentle traction is exerted on the nerve, adhesions are divided after coagulation (Fig. 21.8), and the nerve is transected between two clips. A segment of the nerve is retrieved for histological verification.

Fig. 21.5. Access to the hiatal area: identification of the fleshy portion of the right crus of the diaphragm

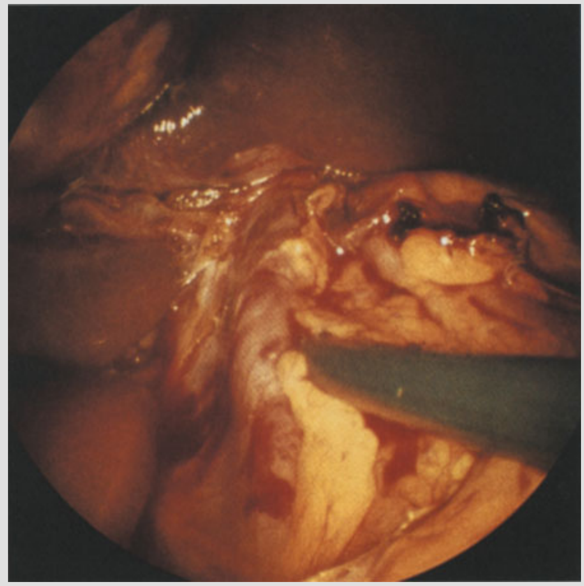

Fig. 21.6. Endoscopic picture of the hiatus. The right crus is exposed

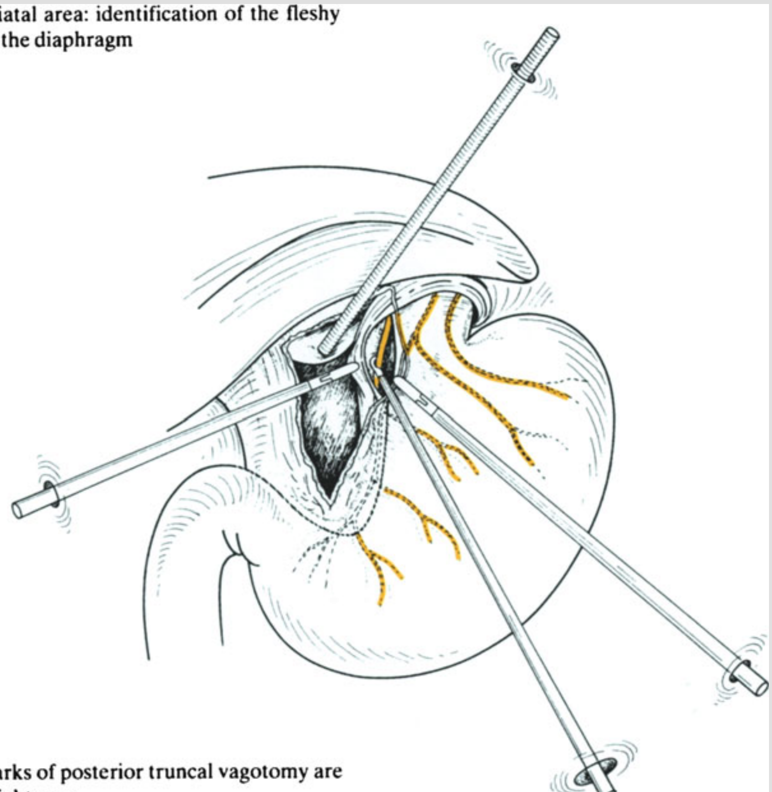

Fig. 21.7. The two landmarks of posterior truncal vagotomy are the caudate lobe and the right crus

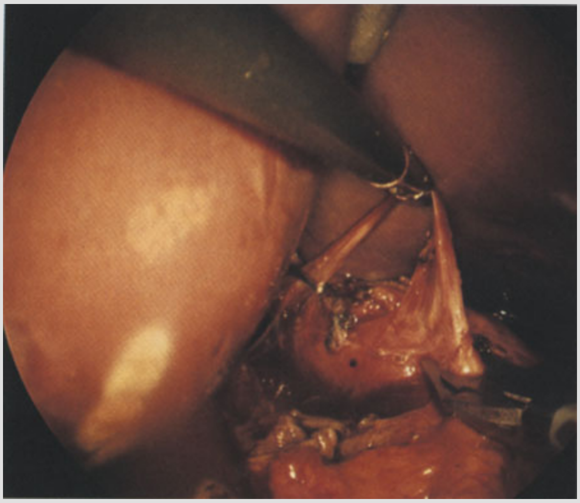

Fig. 21.8. Endoscopic picture showing how the posterior trunk of the vagus nerve is "hooked" in the angle formed by the right crus and the esophagus

Anterior Seromyotomy

The anterior aspect of the stomach is spread out between two grasping forceps. Starting at the esophagogastric junction, the line of incision is outlined by light electrocoagulation (Fig. 21.9) parallel to and situated 1.5 cm from the lesser curvature. The line stops at 5–7 cm from the pylorus at the level of the pes anserinus. The two most distal branches of the nerve are left intact to be sure that the antropyloric innervation remains functional. Seromyotomy is then performed with the hook coagulator using monopolar current, making equal use of the coagulation and division set at average intensity. The hook incises successively the serosal layer, the oblique, and then the circular superficial muscular layers. The two borders are then grasped and gently spread apart mechanically, thus breaking the remaining deep circular fibers. Electrocautery completes the division whenever necessary.

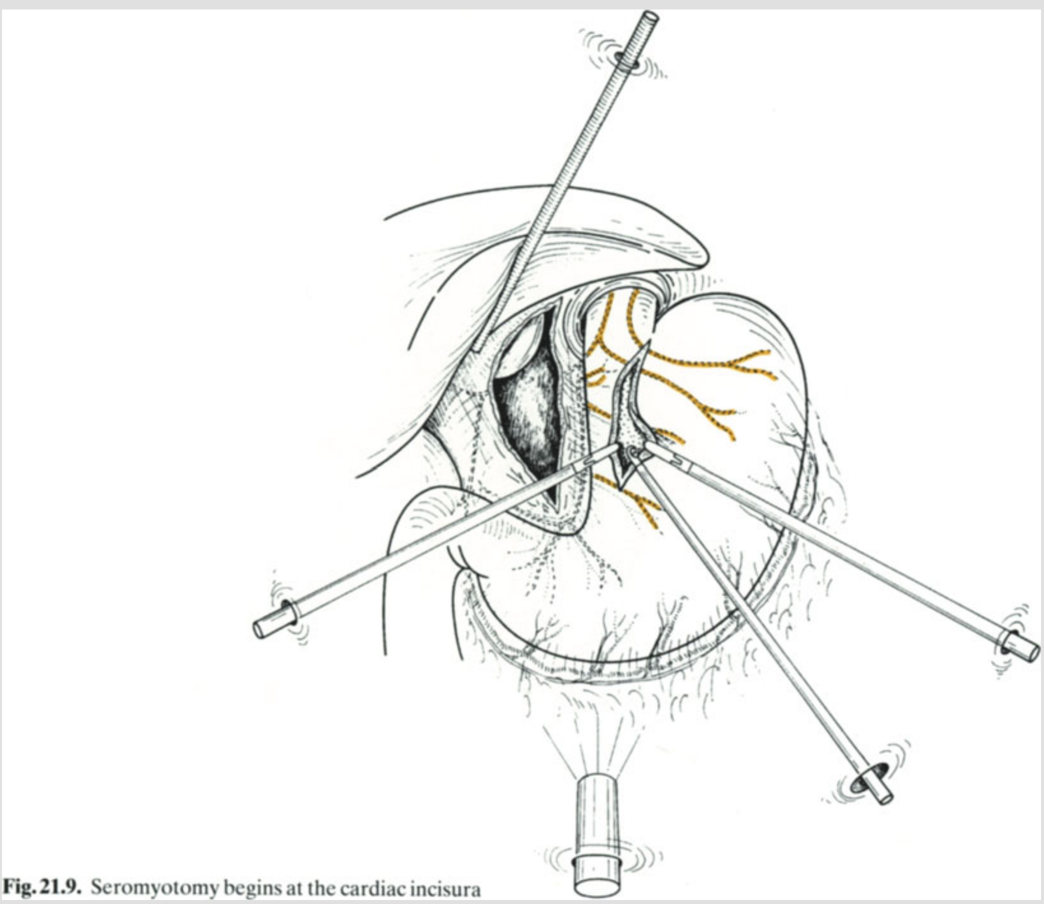

Fig. 21.9. Seromyotomy begins at the cardiac incisura

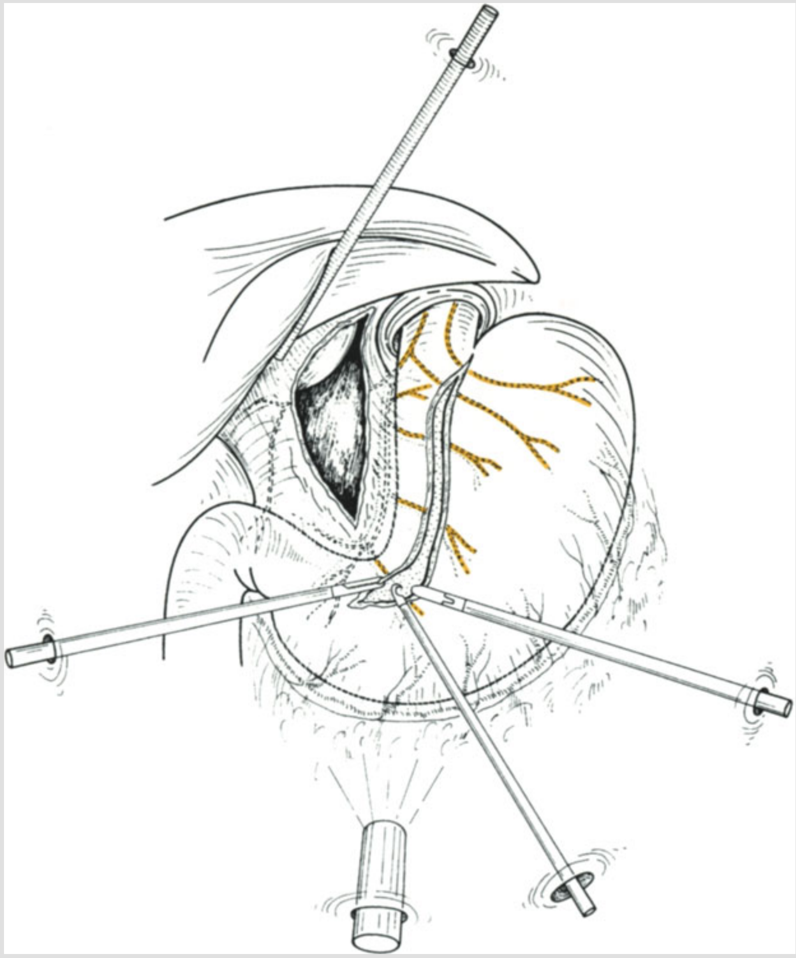

Fig. 21.10. Seromyotomy is continued until the pes anserinus is reached

Once the last muscular fibers have been divided, the mucosa can easily be identified by its typical blue color (Fig. 21.10) as it "pops" out of the incision. Because of the magnification, the surgeon can easily verify that no holes have been inadvertently made. During the incision, two or three short vessels may be encountered. They are divided, as described in Taylor's technique, after identification with the hook coagulator/dissector which lifts them off the seromuscular layer. The ends may be clipped or suture-ligated. It is of utmost importance that the incision be anatomically accurate with perfect hemostasis. Upon completion, seromyotomy appears as a 7–8 mm trench in the gastric wall (Fig. 21.11). Air is then injected through the nasogastric tube to make sure that there are no leaks. The seromyotomy is closed by an overlapping running

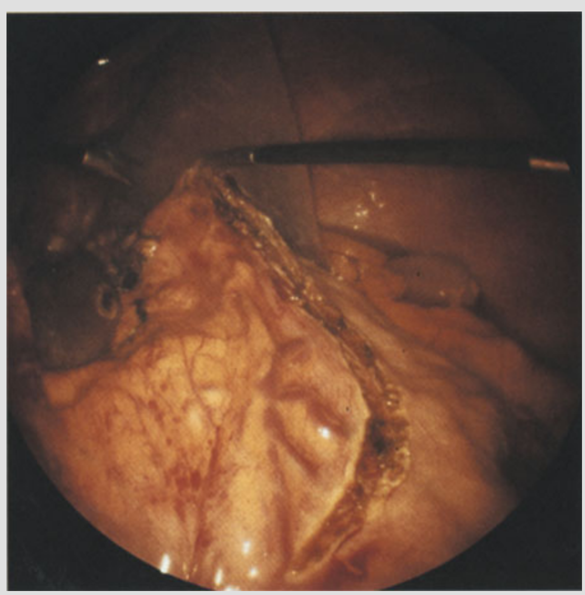

Fig. 21.11. Endoscopic picture of seromyotomy once it has been achieved

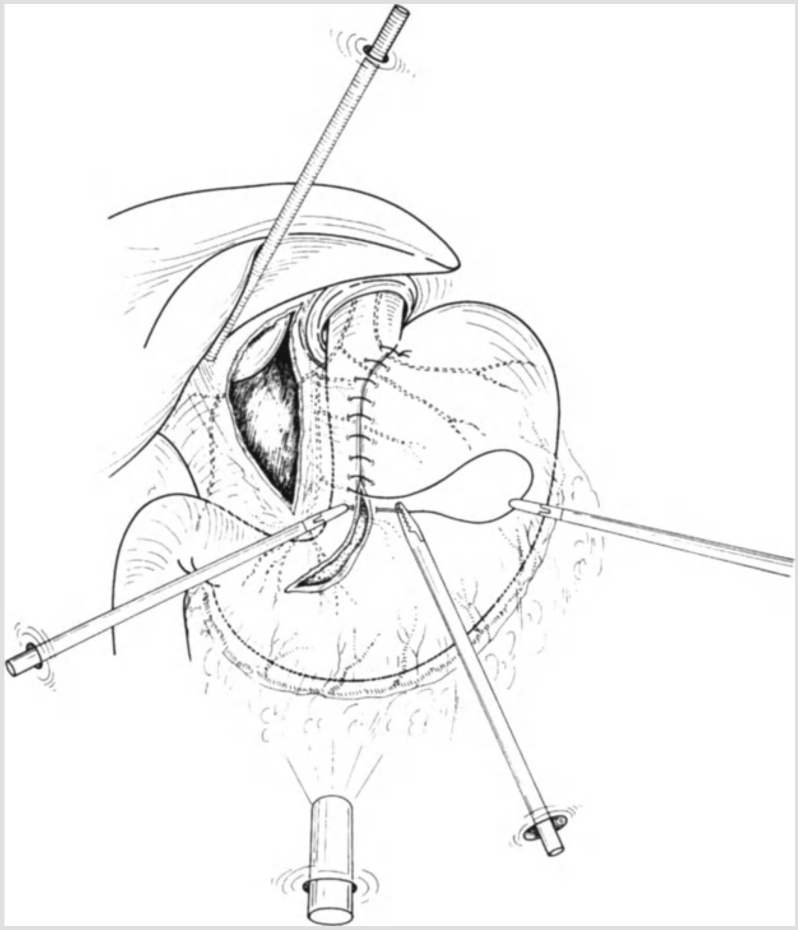

Fig. 21.12. Closure of seromyotomy with running suture (straight needle)

suture (Figs. 21.12, 21.13), knotted at both ends and secured by clips. Fibrin collagen application completes the hemostasis. Abdominal closure is performed without drainage (Fig. 21.14).

Postoperative Management

The postoperative course, as in all laparoscopic procedures, is usually smooth. Postoperative pain is minimized by the fact that the surgical wounds are very small and they are infiltrated with local anesthesia, making systemic analgesia unnecessary. Early ambulation is possible because of the absence of the usual consequences of open abdominal surgery. Patients may resume oral, light soft meals at 24 h and may be discharged 3–5 days after operation, or even before in selected cases.

Clinical Results

Up until December 31, 1990, 28 Taylor's procedures were performed laparoscopically for chronic ulcer disease in our unit. There were eight women and 22 men; mean age was 33 years (range, 19–61 years). Twenty-five patients were symptomatic for at least 4 years with an average of 2.8 relapses per year in spite of well-conducted medical treatment (anti-acids, anti-H_2 and/or omeprazole). Of these patients, five had an antecedent history of hemorrhage which stopped with medical treatment. None of these patients had complications such as hemorrhage or stenosis at the time of operation. Three patients were operated on because of geographical or socioeconomic reasons which made

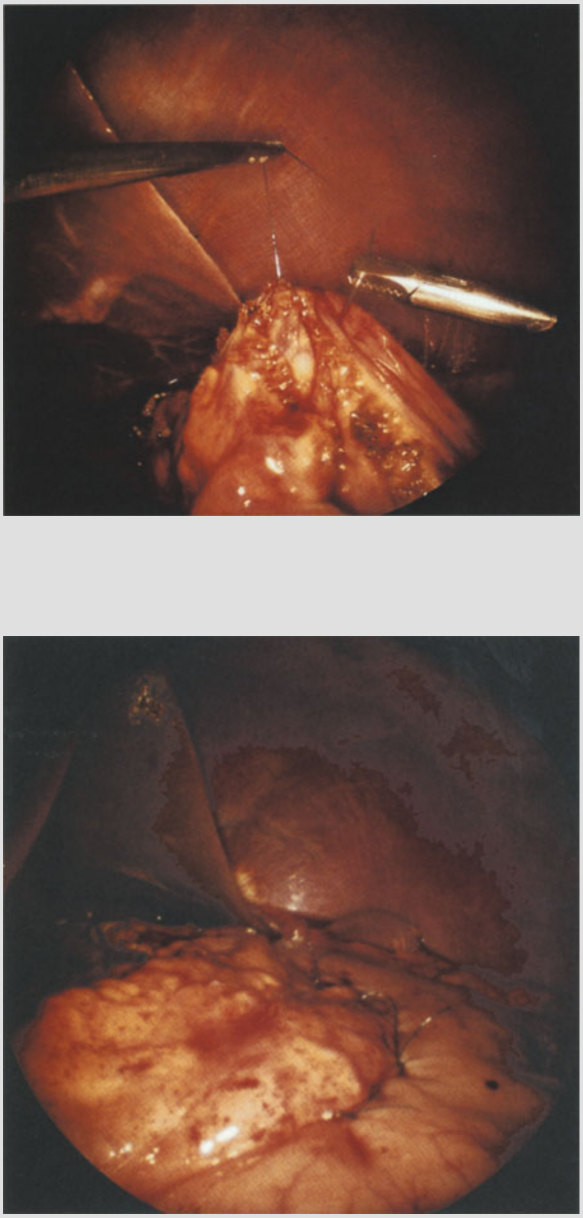

Fig. 21.14. Endoscopic picture of completed suture

long-term medical treatment impossible. There was no mortality. Three patients complained of postoperative fullness which subsided completely with cisapride, and one patient had postoperative reflux requiring reoperation 2 months later. No postoperative functional disorders were found in any of the 24 other patients.

Endoscopic investigations performed 1–2 months postoperatively showed that the ulcer had healed completely in 26 patients while two had residual scars. Secretory studies at 2–12 months documented a fall in BAO and MAO of 79.3%±1.3% and 83.4%±1.2%, respectively.

Results of laparoscopic surgery for this procedure are similar to those of open surgery as reported by Taylor in a multicenter study of 605 patients operated on by 11 different surgical teams with the same method. Postoperative mortality and morbidity were very low as only one postoperative death (0.16%), due to myocardial infarction, was recorded. Necrosis of the lesser curvature or gastric fistula were not observed. Duration of hospitalization was short, as in the case of highly selective vagotomy, i.e., less than 1 week. Digestive comfort was thought to be satisfactory in 94% of patients who were graded Visick I or II. It must be noted, however, that 11.8% of patients experienced gastric emptying difficulties and required further surgery with a drainage procedure. More recently, endoscopic pyloric dilatation has replaced these operations. Subsequent dumping syndrome was not noted, and only two patients complained of persistent diarrhea. Ulcer recurrence occurred in only 1.5% of the total 481 patients operated on during the 5-year period.

Compared to truncal vagotomy, Taylor's procedure was judged to be practically as simple and efficacious as acid secretory reduction was similar and the 5-year recurrence was 3%–6%. The principal advantage, however, was the absence of secondary effects, particularly dumping, diarrhea, and absence of gastric emptying disorders.

Taylor's procedure was as efficient as highly selective vagotomy, as shown by Oostvogel, regarding gastric motility and reduction of acidity. The other advantages, underscored by all the authors who have used this technique, include its reliability, rapidity, and consistency of good results as the anatomical variations in Latarjet's nerve do not influence outcome. This has been confirmed by the experience of several other authors including Triboulet, Kahwaji and Grange, Fourtanier and Escat, and our own series.

Conclusion

Laparoscopic vagotomy according to Taylor is as effective and safe as open vagotomy in the treatment for duodenal ulcer disease untractable to medical therapy. This technique opens up new horizons in the treatment of duodenal ulcer as this therapeutic modality is not invasive and outcome has been uniformly good. Even though medical treatment has improved, the recurrence rate for ulcer disease is approximately 90%

per year, whatever the agent used. These drugs, used widely for more than 10 years, have not decreased the mortality due to complications of ulcer disease, especially in the elderly. For these reasons, as Taylor, we believe that there is still a place for elective treatment of duodenal ulcer, and that the procedure of choice is posterior truncal vagotomy and anterior seromyotomy. Performed by the laparoscope approach, Taylor's procedure represents an improvement that can compete with long-term medical therapy. Clinical outcome and cost effectiveness should be evaluated clinically by a prospective multicentre study. As for all new techniques, however, this new method should be performed with the same patient selection as open surgery in order to ensure that it can be achieved with safety.

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22 Laparoscopic Surgery for Perforated Duodenal Ulcer

L. K. Nathanson and A. Cuschieri

Introduction

Perforation of an ulcer of the first part of the duodenum is not an infrequent surgical emergency. The escape of gastric contents, bile and pancreatic secretions into the peritoneal cavity usually results in peritonitis requiring emergency surgical toilet and closure of the perforation. In selected patients, with radiological evidence of sealed perforation, conservative treatment by nasogastric drainage, intravenous fluids, antibiotics and repeated careful observation may be indicated, especially in high-risk patients.

The majority of patients managed surgically undergo either simple closure of the duodenal perforation with omental patching alone, or in combination with definitive surgical treatment involving some form of vagotomy. The benefits in reduced long-term ulcer morbidity and mortality resulting from the latter approach must be balanced with the increased early morbidity and mortality due to the larger emergency procedure and the distinct possibility for the development of long-term sequelae such as dumping and diarrhoea, especially if a truncal vagotomy and drainage is performed.

The reduction of the trauma of access by the emergency laparoscopic approach has certain advantages. It allows definite confirmation of the diagnosis which is incorrect in 8% of patients managed conservatively. In addition, it carries the potential for accelerated postoperative recovery with decreased pain, earlier mobilization and more rapid return to normal daily activities compared to conventional laparotomy. The laparoscopic approach may well lead to a reduction in the incidence of postoperative respiratory morbidity and overall mortality. Most of these advantages are perceived, however, and require confirmation by reports of large numbers of patients treated laparoscopically.

The laparoscopic approach does not alter the underlying principles for surgery of perforated ulcers. These include good exposure, approximation of tissue without tension, and thorough peritoneal toilet. The limitations of instrumental access using laparoscopic ports entail, however, the use of alternative techniques to achieve these objectives.

Indications and Patient Selection

Laparoscopic treatment of perforated duodenal ulcer should only by entertained by those with experience of laparoscopic suturing and knotting techniques and with the proviso that the necessary equipment is available (see below). In all other respects, the indications are identical to those for conventional open surgical intervention. Specifically, emergency laparoscopic toilet and suture closure for perforated duodenal ulcer is indicated if there is:

1. Clinical evidence for duodenal ulcer perforation.
2. Peritonitis of less than 48-h duration.
3. No history of previous gastric surgery as this is liable to result in extensive dense adhesions in the supracolic compartment particularly around the stomach and duodenum.

In those patients in whom some uncertainty exists as to the suitability for the laparoscopic approach, it is reasonable to commence the operation by this route and convert to a laparotomy as required. No disadvantage to the outcome of the patient is incurred by the adoption of this sequence.

Preoperative Preparation

The preoperative diagnosis is usually clear-cut on clinical grounds and is confirmed by scout chest films taken in the erect position which outline the presence of free air under the right diaphragm. Nasogastric aspiration through an indwelling Ryle's tube is commenced and an intravenous line is set up. Opiate analgesia is started to relieve the pain once the diagnosis is established. Antibiotic therapy is commenced, usually with a broad-spectrum antibiotic such as a second-generation cephalosporin or aminoglycoside.

In all patients informed consent must be obtained with regard to the possible need for conversion to an open operation during the course of the procedure.

Anaesthesia

The procedure is undertaken under general endotracheal anaesthesia with muscle relaxation and controlled ventilation. Prior to induction, the Ryle's tube is aspirated to ensure that the gastric reservoir is empty and thus prevent inhalation. The urinary bladder is catheterized but the catheter is removed at the end of the operation.

Patient Positioning and Skin Preparation

The patient is operated on in the supine position with a head-up tilt. As the position of the table will require to be changed, particularly during the aspiration and saline irrigation of the peritoneal gutters and pelvis, it is wise to strap the patient to the operating table. The entire anterior abdominal wall is cleaned with medicated soap and skin antiseptic applied. The operative field is isolated with sterile drapes in a manner identical to that used in open surgical treatment of perforated duodenal ulcer.

Layout of Ancillary Instrumentation and Positioning of Staff

The surgeon operates from the left side of the patient with the assistant and scrub nurse on the opposite side. The exact layout of the ancillary instrumentation depends on the configuration of the operating theatre, but, if possible, the electronic insufflator, telescope warmer, light source, diathermy, suction and irrigating systems should be stacked behind the surgeon.

Details of Specific Instrumentation and Consumables

In addition to the standard laparoscopic equipment, the following instruments are needed:

1. Suture applicator
2. Semm's needle holders (3.0 and 5.0 mm)
3. Cook's curved needle driver (5.0 mm)
4. Expanding retractor

The suturing is performed with either polydioxanone or polyglactin or 3/0 atraumatic sutures (polysorb endoski needle).

Operative Steps

Exposure

Peritoneal insufflation is performed using a Veress needle inserted for this purpose. CO_2 is insufflated using an electronic insufflator with automatic high-flow capability. The presence of scarring in the area of the umbilicus may indicate the use of other techniques for safe induction of the pneumoperitoneum (see Chap. 13). The cut-off pressure for the insufflator should be set at 12.0 mm Hg.

The positions of the cannulae through the anterior abdominal wall are shown in Fig. 22.1. The technique for insertion of the initial cannula is dependent on the surgeon's suspicion of the presence of underlying peritoneal adhesions. In the unscarred abdomen, the ini-

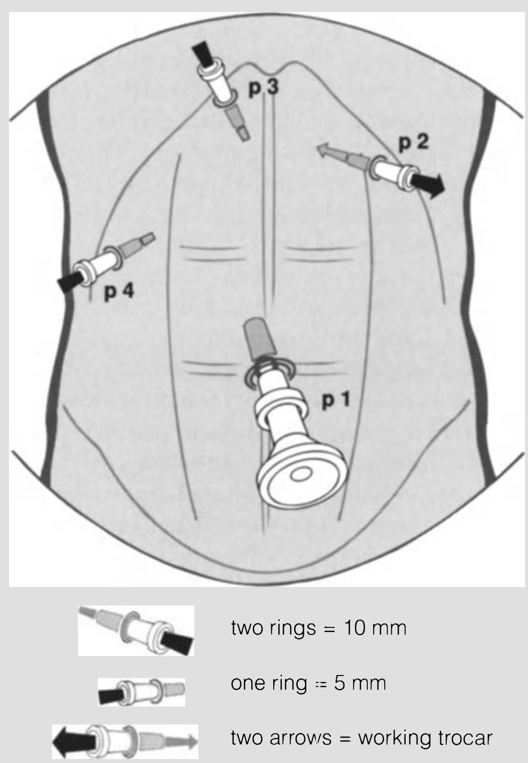

Fig. 22.1. Optimal sites for the cannulae. One of the lateral 5.5-mm cannulae may need to be replaced by an 11.0-mm during the course of the operation

tial 11.0-mm trocar and cannula assembly is inserted in the subumbilical region using the blind puncture technique. The 30° forward-oblique laparoscope with attached charge-couple device (CCD) camera is then inserted allowing further progress of the operation to be followed on the video screen. The three accessory 5.5-mm cannulae are placed under direct visual control. The exact location of the accessory cannulae is dependent on the degree of obesity of the patient and the situation of the perforation. The key to good exposure and expeditious suturing is to ensure that the tips of the two instruments used by the surgeon meet at right angles to each other in the operative field, with the third port used by the assistant for the retraction of the liver.

Most adhesions following previous abdominal procedures are located in the region of the scar and in the area of the peritoneal cavity where the surgery was performed. Insertion of the Veress needle and insufflation at a site remote from both these regions is therefore likely to minimize the risk of bowel injury. Prior to commencing insufflation, aspiration of the Veress needle with a syringe (to detect blood or bowel content) and injection of saline to confirm free peritoneal placement of the needle tip are wise precautions.

In patients with suspected adhesions after the pneumoperitoneum is established, the area selected for the initial blind cannula insertion should be sounded with a long 22-gauge needle attached to a saline syringe to assess the extent of the safe cushion available for the trocar and cannula insertion (see Chap. 13). Once the surgeon is satisfied that the underlying parietal peritoneum does not have adherent viscera, a 5.5-mm cannula is inserted blindly and the 5.0-mm laparoscope used to visualize the peritoneal cavity. The cannula can then be replaced by the 11.0-mm one using the dilating system (see Chap. 13) for insertion of the 10.0-mm 30° forward-viewing telescope attached to the CCD camera. All the other cannulae are inserted under direct visual guidance. If the sounding test indicates the presence of adhesions over a wide area, either the laparoscopically guided technique of cannula insertion or open laparoscopy should be employed (see Chap. 13).

Assessment of the Perforation

The perforation is viewed by gentle elevation of the overlying edge of liver and downward retraction of the pylorus (Fig. 22.2). Tilting the patient 20° head-up will facilitate exposure by caudad movement of the transverse colon, omentum and small bowel. The suction cannula introduced at this stage allows a clearer view by aspiration of escaped bowel content and inflammatory exudate. The ulcer size, degree and extent of inflammatory oedema of the duodenal wall and preexisting fibrosis determine whether the perforation can be closed by simple direct suture (with or without reinforcement by omental flap overlay) or by the omental onlay patch or omental plug techniques.

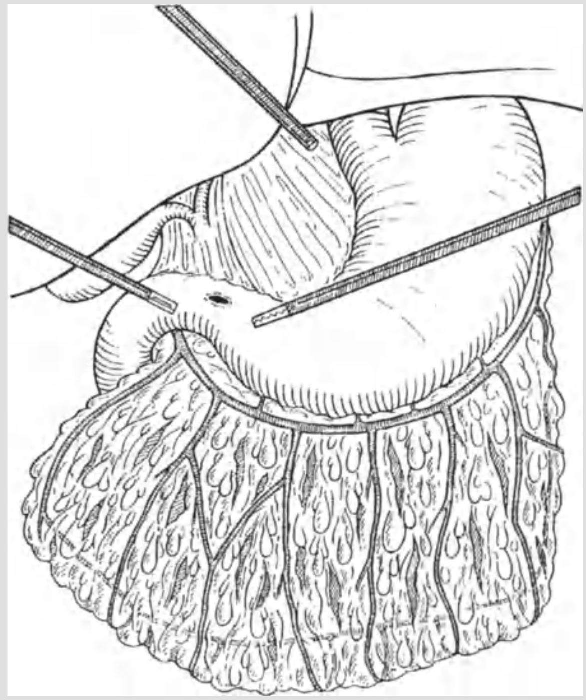

Fig. 22.2. Exposure of the perforation

Suturing Techniques

The atraumatic sutures used are polyglactin, or polydioxanone or polysorb mounted on Endoski needles. The technique for introduction of the needle and suturing is that originally described by Semm (1987). This technique is reliable and avoids gas leaks. Unfortunately, the limitations of the straight needle restrict its use with very oedematous tissue as inadvertent tearing during needle placement can easily occur. Half-circle round-bodied needles can be used but the easiest suturing is carried out using the endoski needle and a 5 mm needle holder. The insertion of atraumatic sutures mounted on half-circle needles can only be achieved by loading them inside a reducer tube which is then inserted through an 11.0-mm accessory cannula.

After the suture (which should not exceed 8.0 cm in length) is passed through healthy tissue across the perforation, it is tied internally using the standard microsurgical knot (see Chap. 7). This technique of internal knotting requires patience and a great deal of prior practice to perform smoothly. Whilst performing suturing, it is desirable for the surgeon to view the operative field by direct observation down the laparoscope, with a beam splitter maintaining the view on the video screen for use by the assistant and scrub nurse. The definition and depth perception by direct monocular vision is far superior to that obtained by the present generation of CCD cameras and greatly facilitates precise suture placement.

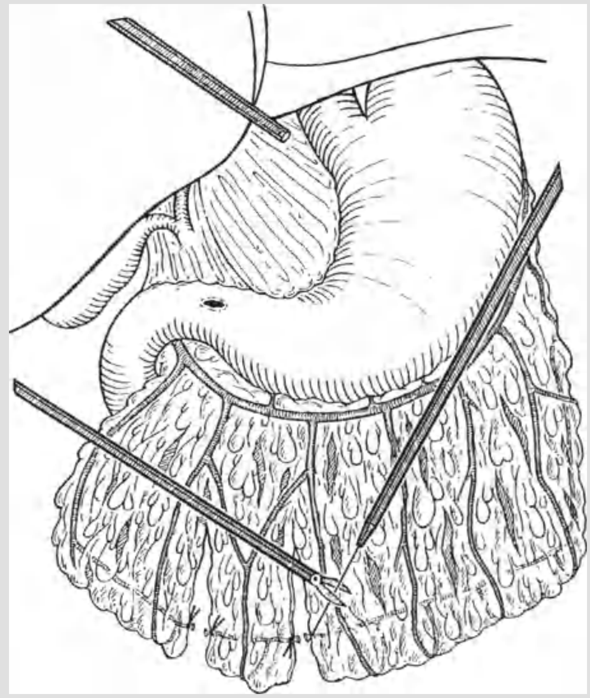

Fig. 22.3. Preparation of the omental pedicle. This is based on a suitable vascular axis, the side branches of which are ligated or clipped. During this process, care must be taken to preserve the vascular supply and venous drainage of the epiploic arcades

Repair of the Perforation

Direct Suture Closure

Small perforations of less than 5.0 mm in diameter with surrounding healthy duodenal wall can often be closed by direct suture using the endoski needle mounted on a 5.0-mm needle holder. The early sealing of the duodenum by this technique allows the operative field to remain clean as the omental overlay is fashioned if this is considered necessary. Judgement must be exercised in the selection of the perforations closed in this fashion. In practice, the key factor is that a fresh perforation with healthy adjacent duodenal wall is best able to hold sutures without cutting out. The choice of closure, either transverse or longitudinal, is dependent on the laxity of the anterior duodenal wall. If considered necessary, an omental flap may be laid over the closed perforation and tacked in position by a few seromuscular sutures.

Mobilization of the Greater Omentum

As in open surgery, selection of the omental pedicle to use as a patch depends on the individual's omental attachments and its mobility, which is restricted when it is fat laden in obese individuals. In those patients in whom mobilization of the omentum is required to ensure that the omental pedicle lies in the desired position without tension, the technique used is to ligate (or clip) the side branches of the vascular pedicle as shown in Fig. 22.3. During this step, care must be taken to preserve the vascular supply and venous drainage of the epiploic arcades. If clips are used to secure the side branches, care must be taken to avoid brushing against these as this may lead to their slipping. If, in the construction of the omental pedicle, a haematoma forms within the omentum, this is best secured by an endoloop.

On-lay Closure with Omental Patch

Sutures are placed as shown in Fig. 22.4. The suture which fixes the apex of the omental pedicle to the duodenum proximal to the perforation is placed last. Tying is, however, in the reverse order with the apical suture being tied first, followed by tying of the two remaining transmural duodenal sutures which cross the perforation.

Omental Plug Closure

Friability and oedema of the margins of the ulcer and adjacent duodenal wall are encountered in late cases. In these situations, great care must be taken during the exposure of the perforation to avoid its enlargement by instrument trauma. It may be possible to close some of these perforations by the on-lay omental closure

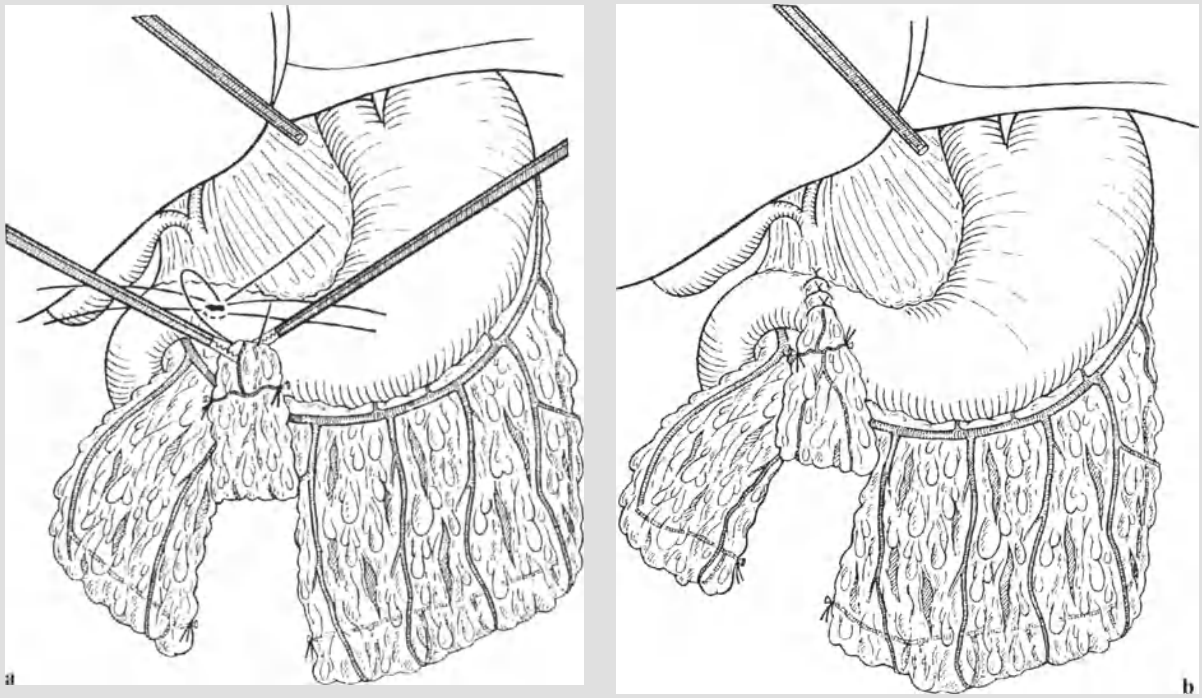

Fig. 22.4 a, b. Technique of on-lay closure with omental patch. **a** Sutures are placed through the duodenal walls across the perforation. The suture which fixes the apex of the omental pedicle to the duodenum proximal to the perforation is placed last. **b** The sutures are tied in the reverse order: the apical suture first, followed by tying of the two remaining transmural duodenal sutures

technique described above. However, placement of sutures must be conducted with great care ensuring that good "bites" of the full thickness of the duodenum away from the ulcer margin are taken. This type of ulcer necessitates the use of half-circle or endoski needles as described in the previous section.

Difficulties are also encountered when chronic recurrent ulceration has resulted in severe fibrosis which, combined with the rigidity and inflammatory oedema, can make direct suture or on-lay omental closure as described above extremely difficult, if not impossible. In this situation, the ideal treatment (as in open surgery) is to fashion a wide omental pedicle and then insert its apex as a plug inside the perforation (Fig. 22.5). The edges of the pedicle are then tacked to surrounding healthier tissues by a few interrupted seromuscular sutures to achieve fixation of the plug.

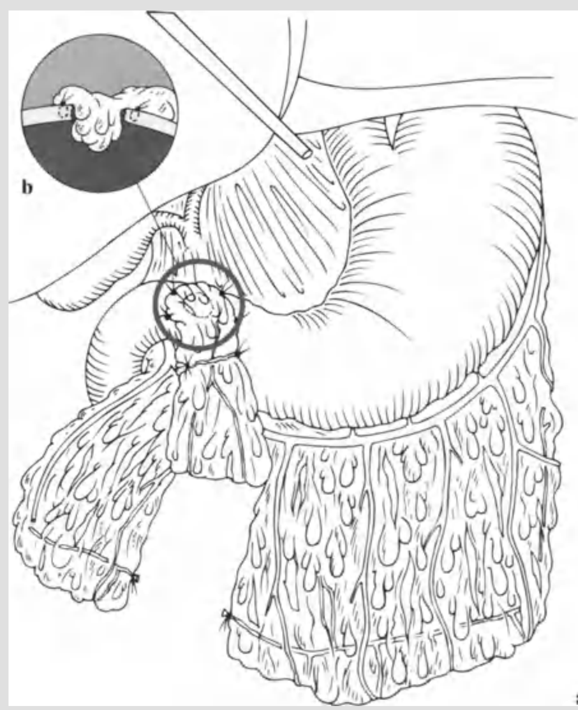

Fig. 22.5 a, b. Technique of omental plug closure. **a** A wide vascularized omental pedicle is fashioned. **b** Its apex is then inserted inside the perforation as a plug. The edges of the pedicle are then sutured to surrounding healthier tissues by a few interrupted seromuscular sutures to achieve fixation of the plug

Conversion to Open Surgery

The situations which necessitate immediate conversion to open surgery are:

1. The presence of a large perforation where closure by any of the above techniques cannot be safely achieved.
2. Significant duodenal and or pyloric stenosis when simple repair is likely to aggravate the stenosis.
3. Failed attempted closure for any reason.
4. Unsuspected additional pathology which requires open intervention.

Peritoneal Toilet

Peritoneal toilet is accomplished by pressurized warm saline irrigation and suction of purulent exudates, escaped gastrointestinal contents and blood clot. Both aspiration and irrigation are effected through the same cannula, which incorporates finger tip-controlled trumpet valves to activate either system. The peritoneal toilet is commenced initially in the right upper quadrant, then the left side of the supracolic compartment, followed by the infracolic compartment and the pelvis. Toilet of the latter region entails a steep Trendelenburg tilt of the patient. This is aided by manipulation of the small and large bowel using bowel-grasping forceps.

Problems may be encountered during peritoneal toilet. Thorough clearance of bowel content and inflammatory exudate is tedious and time consuming. It often takes longer than the closure of the perforation. After aspiration of contaminated fluid, repeated cycles of irrigation with small volumes of warmed saline followed by aspiration achieve good dilution and reasonable peritoneal decontamination. Large irrigation volumes are less effective and enhance the ease with which the end hole of the suction cannula is occluded by omental fat and appendices epiploicace. Alteration of sucker design along the lines of sump suction simply deflates the pneumoperitoneum at the same time and so slows progress due to loss of exposure. The key to speeding up aspiration is to activate the suction only when the instrument tip is below the surface of the liquid whilst retracting omental fat, appendices epipoicae and bowel to prevent obstruction of the tip of the sucker. Very high suction pressure can also slow progress by the increased tendency to sucker tip occlusion by surrounding structures. Turning down this suction pressure to an optimal level minimizes this problem while still removing large volumes of fluid quickly. Large particles of escaped food debris are removed by spoon forceps, a large version of which can be introduced down the 11.0-mm cannula.

Great care must be exercised in handling bowel to avoid its injury during manipulation and retraction. Specifically designed bowel-grasping forceps will minimize this risk. The tip of the sucker is likewise potentially able to injure structures such as the liver and spleen. This is most likely to occur if the instrument is advanced without adequate visual control.

At the end of the procedure, a 5.0-mm silicon drain may be inserted and placed in the subhepatic region if this is considered desirable. The pneumoperitoneum is desufflated, the cannulae withdrawn slowly and the wounds sutured with subcuticular polyglactin. A separate fascial stitch to the linea alba is desirable to prevent hernia formation through the subumbilical wound.

Postoperative Care

The nasogastric drainage is usually maintained for 24 h. Gradual introduction of oral fluid is made as tolerated by the patient. Solids are usually well tolerated by the 3rd or 4th postoperative day. Early mobilization is encouraged and is usually achieved by the 3rd postoperative day. The majority of patients will require narcotic analgesia during the first 24 h. Unless the perforation is late, antibiotic therapy is stopped after the third dose administered 24 h after surgery. Discharge is usually by day 5, but of course is influenced by age and associated debility. Full therapeutic doses of an H_2 receptor antagonist are continued for 3 months and followed by maintenance therapy for at least a further 12 months. The present experience with the procedure is limited and final assessment of its advantages must await the analysis of large longitudinal studies.

Future Developments

Fibrin Glue Sealing of Perforations and Omental Patching

We have used this technique in the experimental setting. Clinical success has also been reported in four patients. The obvious attractions of this technique include simplicity and ease of execution. However, at present caution is needed as the safety of the method is by no means certain or assured. There are a number of reasons for this. In the first instance, the ideal formulation of fibrin glue in terms of the concentrations of the various clotting factor components has not been ascertained, particularly with regard to its effect on wound healing. Secondly, the laparoscopic delivery system of the fibrinogen and activating factor solutions requires further development. Thirdly, the optimal technique to achieve sealing of bowel perforation, i. e. the fibrin plug on its own or sandwiched with overlying omentum, remains to be determined by the on-going studies in our department. In the experimental setting we have observed marked variation in the efficacy of this fibrin glue-based technique in providing complete immediate sealing of the perforation. Until further data are available, this modality of controlling bowel perforation, while attractive, must be viewed as experimental.

"Definitive" Laparoscopic Ulcer Surgery

Elective laparoscopic operations for patients with duodenal ulceration unresponsive to medical management are being introduced. Highly selective vagotomy, truncal vagotomy and pyloric dilatation (Dubois in Paris) and posterior truncal vagotomy combined with anterior seromyotomy (Mouiel et al. in Nice, Cuschieri et al. in Dundee) have been performed. The short- and long-term results of these procedures wil be of interest, especially for surgeons with a preference for treating patients presenting with acute duodenal ulcer perforation with "definitive" surgery. Realistically though, at present these operations take some 2–3 h to complete and are therefore some way off being ready for routine use in the emergency setting.

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23 Laparoscopic Antireflux Surgery

A. Cuschieri, L. K. Nathanson, and S. M. Shimi

Introduction

Oesophageal reflux disease is one of the most common disorders of the gastrointestinal tract. Treatment with H_2 blockers and alginates provides symptomatic relief in the majority of cases, but is less effective in inducing healing of the inflamed oesophageal mucosa. Moreover, recurrence of symptoms is invariable with cessation of medical therapy. Omeprazole has been shown to be a more effective treatment in a number of clinical trials. However, there is concern in relation to the long-term effects of complete achlorhydria induced by this proton pump inhibitor. Surgical treatment is usually reserved for failure of medical treatment to control symptoms, non-compliance with medication and onset of complications. The most common procedure performed is some form of total or incomplete fundal wrap (fundoplication) performed through the abdominal approach, although thoracic procedures such as the Belsey mark IV operation are equally effective. Although the results of total abdominal fundoplication are good, this procedure is often complicated by the gas bloat syndrome. Partial fundoplication, particularly that described by Toupet, is free of this distressing side effect, and recent studies have confirmed its efficacy as an antireflux procedure. The ligamentum teres (round ligament) sling procedure reported Narbona-Arnau et al. in 1965 has been well validated as an effective low-morbidity option which lengthens the abdominal segment and increases the pressure at the lower oesophageal sphincter without incurring adverse effects associated with total plication of the fundus, e. g. dysphagia, inability to belch and the gas bloat syndrome. The essential feature of the cardiopexy of Narbona-Arnau consists of suture fixation of the round ligament sling to the oesophagogastric (OG) junction and anterior wall of the stomach (Fig. 23.1). In the operation reported by Rampal et al. in 1964, the end of the ligamentum teres sling is attached to itself. This antireflux procedure is similar in concept to the modern Angelchick prosthesis and has certain potential disadvantages. These include the real risk of slipping of the OG junction through the sling. There are no large reported series of the Rampal cardiopexy.

We have adapted both the Narbona-Arnau, and the total or partial fundoplication for surgical laparoscopic treatment of symptomatic reflux disease unresponsive to medical treatment.

Indications and Patient Selection

Indications

The operation is indicated:

1. If medical treatment has failed to control symptoms.
2. For the development of complications.

Failure of Medical Therapy

In addition to conservative measures such as weight reduction, postural and dietary advice, active medication includes the use of H_2 blockers, alginate preparations, prokinetic agents and, more recently, the proton pump inhibitor omeprazole. Often treatment consists of a combination (alginates and H_2 blockers) since some clinical trials have shown that this is more effective than single-agent therapy alone. There is no evidence that mucosal protective agents are helpful in reflux disease. Undoubtedly, omeprazole, which abolishes all gastric secretory activity, is the most effective agent in terms of symptomatic relief and healing of the oesophagitis. However, there is genuine concern on the adverse effects of long-term therapy with this proton pump inhibitor in terms of the development of gastric tumours, particularly of the enterochromaffin cells. This drug is therefore reserved for treatment of elderly patients (>60 years).

Failure of medical therapy may be due to either poor compliance or resistant disease. In either case, surgical treatment is necessary, especially if the patient is young or middle aged.

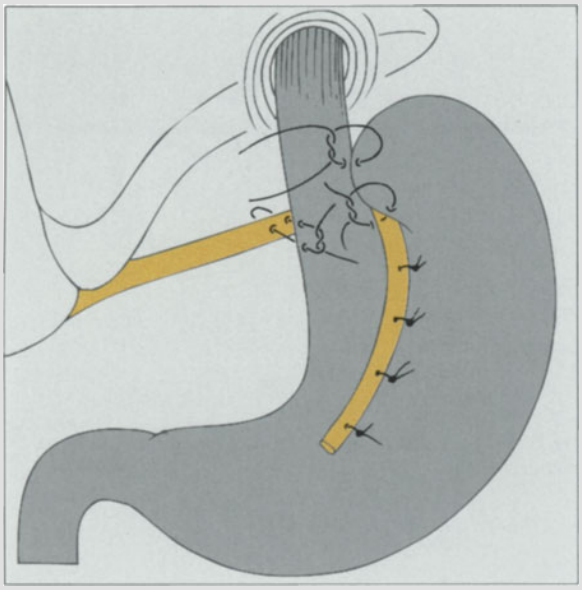


Fig. 23.1. Technique of ligamentum teres cardiopexy of Narbona-Arnau et al.

Onset of Complications

The most common complication necessitating surgical treatment is stricture formation. Dilatation of the stricture may be performed before or at the time of surgical treatment. Another indication is the development of Barrett's columnar change (metaplasia) as there is some evidence that control of acid reflux results in regression of the metaplastic change although this is still a controversial matter. Bleeding from the erosive oesophagitis is not a common indication for surgical treatment except when it is recurrent and leads to iron deficiency anaemia.

Patient Selection

Both procedures are difficult (though not impossible) in the obese. Weight reduction in these patients is highly desirable because it facilitates the hiatal dissection. Both operations can be performed in the presence of a hiatus hernia provided this is not accompanied by significant oesophageal shortening. If detectable, the latter constitutes a contraindication to laparoscopic antireflux surgery. These procedures are also inadvisable if severe dysplasia is documented on the oesophageal biopsy. These patients are best treated by oesophageal resection because of the high incidence of in situ or early invasive cancer.

We do not have enough data and adequate follow-up to compare the efficacy of the two laparoscopic operations. Currently, our practice is to decide on laparoscopic inspection which of the two operations is more technically feasible in the individual patient. In general, fundoplication is difficult and hazardous if the splenic hilium encroaches on the fundus such that the working distance between the left margin of the OG junction and the spleen is restricted. The mobilization of the round ligament is difficult in the presence of adhesions, if the round ligament lacks a falciform mesentery for most of its length and if it is heavily fat laden.

Preoperative Work-up and Preparation

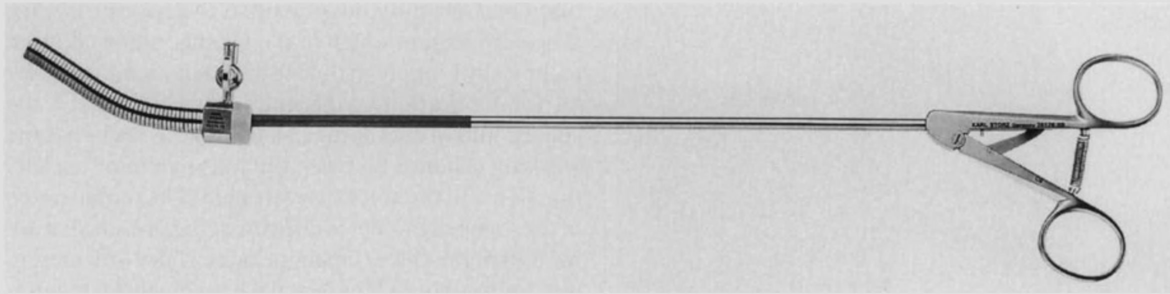
In addition to routine tests aimed at assessing fitness for general anaesthesia and operation, the following investigations are necessary in these patients to assess the severity of the disease and to establish the need and suitability for laparoscopic antireflux surgery: upper gastrointestinal endoscopy and biopsy (to document disease severity and complications), barium swallow (for the documentation of type, size and incarceration of any associated hiatus hernia), 24-h ambulatory pH monitoring (to confirm presence and pattern of reflux and efficacy of the lower oesophageal clearance mechanism) and oesophageal transit using the radio-labelled solid bolus test which must not be significantly delayed. If the oesophageal transit is abnormal, further testing with oesophageal manometry is needed to identify the presence and nature of any associated motility disorder.

Anaesthesia

Both procedures are performed under general anaesthesia with endotracheal intubation. The exact details and premedication vary with the practice of the anaesthetist. Antibiotic prophylaxis is not administered routinely in these patients. A nasogastric tube is inserted, and the stomach is kept deflated. This is essential for the visualization of the abdominal oesophagus and the OG junction. The patient's urinary bladder is catheterized.

Patient Positioning and Skin Preparation/Draping

Positioning is identical for the two procedures. The patient is placed on the operating table in the supine position with 15°–30° head-up tilt with the surgeon operating for the most part from the left side of the patient.



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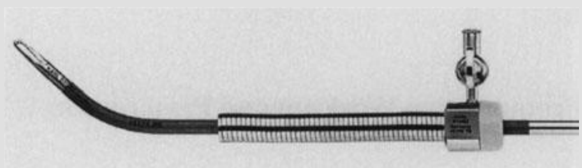


b

Fig. 23.2 a, b. Curved atraumatic grasper and flexible metal cannula (Storz)

The skin is prepared with medicated soap (Hibiscrub) and then disinfected with the antiseptic of choice. The area prepared in this fashion extends from the nipple line to the pubis and laterally to the flanks. Draping is similar to that for laparoscopic cholecystectomy. It is important that the entire costal margin is included in the operative field. If a pneumatic laparoscope holder (First Assistant, Leonard, Philadelphia) is used, the unsterile stem is fixed to the rail of the operating table towards the foot and on the left side.

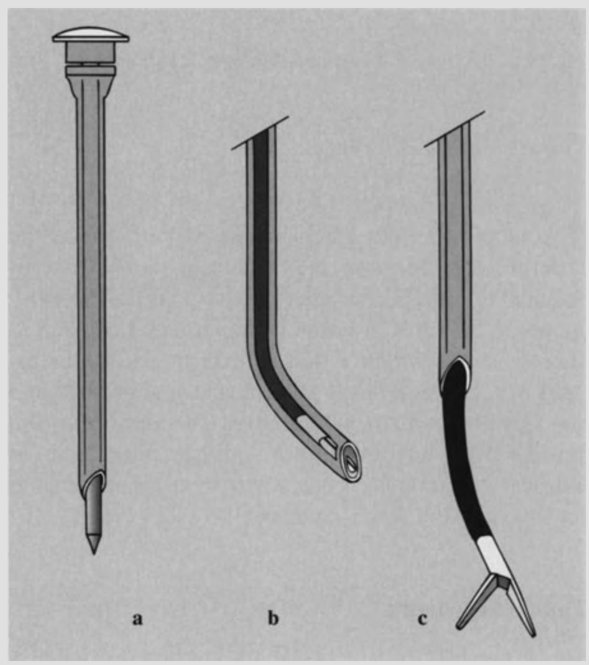


Fig. 23.3. **a** Flexible 5.5-mm trocar and cannula. **b** Cannula without metal trocar (Storz) with curved instrument being introduced. **c** Curved instrument after passage through flexible cannula

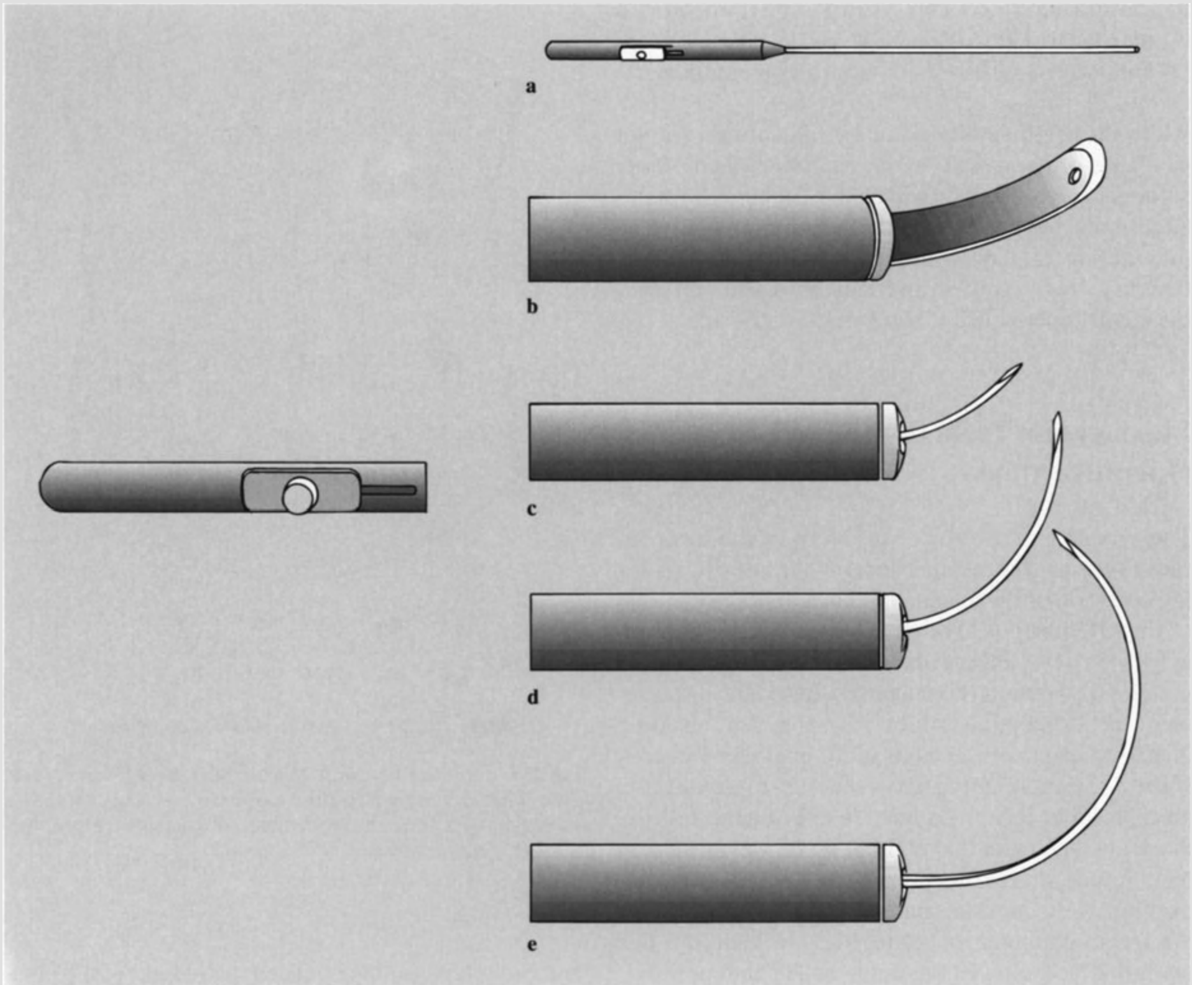
Layout of Ancillary Instruments and Positioning of Staff

Most of the surgery is performed with the surgeon operating from the left side, although some stages of the ligamentum teres cardiopexy (e.g. suturing of the teres ligament to stomach) are more easily conducted from the right side. For both operations, the assistant and scrub nurse are situated on the right side of the patient. The layout of the ancillary equipment is similar to that used in cholecystectomy. It is essential that a two-monitor visual system is available as the assistant plays a very active role in the dissection of the hiatus in both procedures and in the mobilization of the teres ligament from the falciform fat during the ligamentum teres cardiopexy.

Detail of Specific Instruments and Consumables for the Procedure

In addition to the basic instrumentation, the following special equipment is necessary for both procedures:

1. 10.0-mm 30° forward-oblique telescope
2. Curved atraumatic grasper (Fig. 23.2)
3. Flexible trocar cannula (Fig. 23.2, 23.3) or variable curvature pseudoelastic spatula (Fig. 23.4)
4. Endoretractor (Fig. 23.5)
5. Umbrella (expanding) retractor rod (Storz)
6. 3.00- and 5.00-mm needle holders
7. Suture applicator
8. Push rod for Roeder slip knotting in continuity



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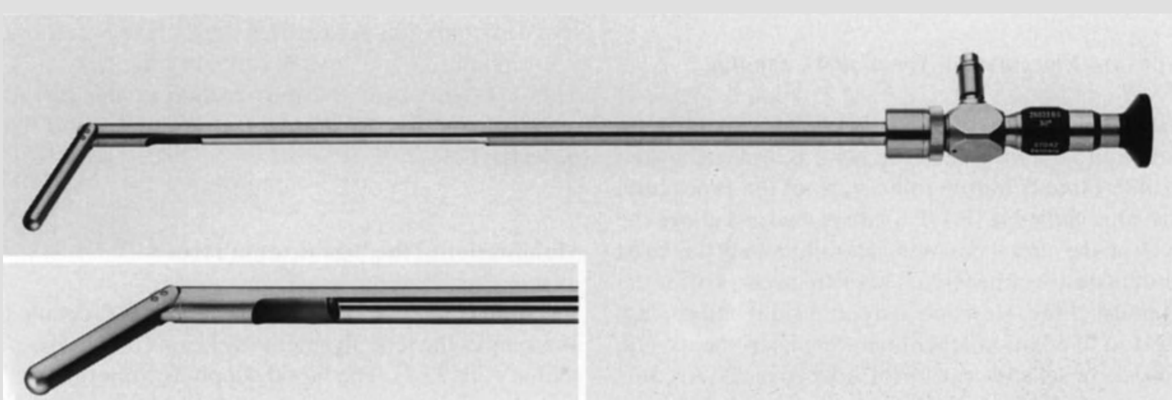


23.5

Fig. 23.4 a–e. Variable curvature pseudoelastic dissecting spatula. The curvature is increased by progressive extrusion of the pseudoelastic blade

Fig. 23.5. Dipping endoretractor for use with the 10.0-mm 30° forward-oblique telescope. The components include the terminal hinged retractor bar, the viewing cut-out (15 cm) and long cylindrical stem (Storz)

9. Consumables: endoclip (AutoSuture), silicon vascular tapes, Ethicon or USSC ski needle-mounted (non-swivel) 3/0 black silk, laparoscopic sutures

If the ski needle-mounted black silk sutures are not available, ordinary half – circle round – bodied 3/0 silk sutures can be used, provided the needle is straightened along the shaft to the ski configuration. Silk is the only suture material that locks well after the first double throw and therefore facilitates and enhances the quality of laparoscopic interrupted suturing.

Ligamentum Teres Cardiopexy – Operative Steps

The procedure reproduces the steps of the ligamentum teres cardiopexy of Narbona-Arnau except for the omission of the anchoring suture on the right side of the OG junction. We omitted this suture to minimize the risk of devascularization of the round ligament and to obtain the maximal downward displacement of the OG junction by the sling. The resulting increased length of the intra-abdominal segment constitutes the most important aspect of the antireflux mechanism of this procedure. In accordance with La Place law, the extended abdominal oesophageal segment is then able to function as a flutter valve with apposition of the anterior and posterior walls whenever the intra-abbominal pressure rises. In addition, this operation accentuates the angle of His and approximates the folds of the mucosal rosette at the cardio-oesophageal junction.

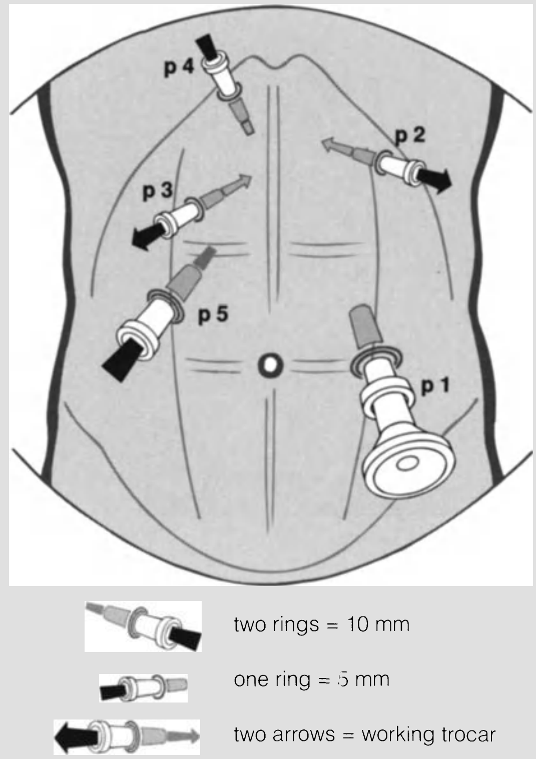


Fig. 23.6. Sites for the trocar and cannulae used for the procedure. The 5.5-mm cannula close to the left costal margin (*p2*) is subsequently replaced by the flexible one to enable the introduction of the curved grasper

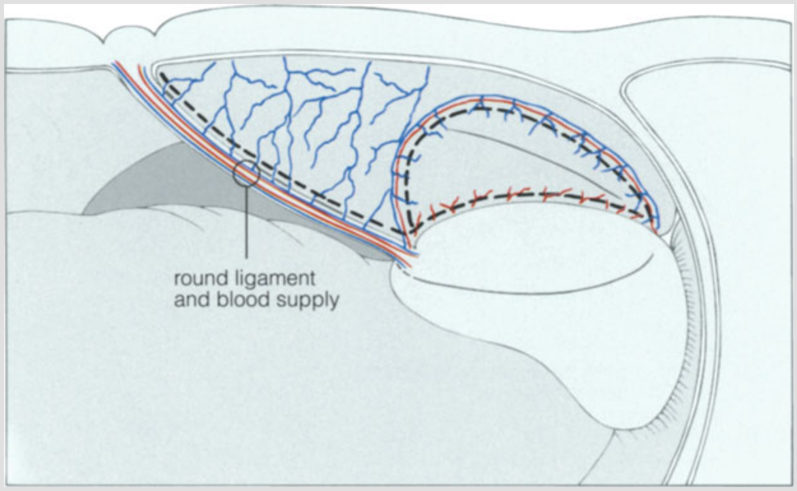
Types and Placement of Trocar and Cannulae

Five cannulae are required (Fig. 23.6): two 11.5 mm and three 5.5 mm. One of the latter is replaced by the flexible cannula during some steps of the procedure. The large cannulae (P 1, P 5) are placed just above the level of the umbilicus well laterally along the linea semilunaris on either side. These are necessary for the insertion of the telescope (on either side) and clip applicator. In addition other operating instruments, e. g. graspers or scissors, can be introduced inside a reducing tube.

The upper 5.5-mm trocar and cannula assembly is placed below and to the right of the xiphoid (P 4) and is used to introduce the expanding retractor rod which is used to lift the left lobe of the liver prior to the insertion of the endoretractor. The second 5.5-mm trocar and cannula assembly is placed to the right of the linea alba (P 3) equidistant between the upper small cannula and the right 11.5-mm cannula. The third 5.5-mm cannula is inserted close to the lower end of the left costal margin (P 2). At a certain stage of the procedure it is replaced by the flexible cannula (Fig. 23.2, 23.3). This is essential for the introduction of the curved graspers used for the insertion of a sling around the oesophagus.

Mobilization of the Ligamentum Teres

An appreciation of the vascular supply and detailed anatomy of the teres ligament/falciform complex is essential (Fig. 23.7). The blood supply is from the liver and the peritoneal attachments. A vascular arcade which is fed by hepatic branches runs parallel and close to the teres ligament as far as the umbilicus and must be preserved. Above the liver, the two layers of peritoneum are closely opposed, forming a translucent window which is outlined by a peripheral vascular



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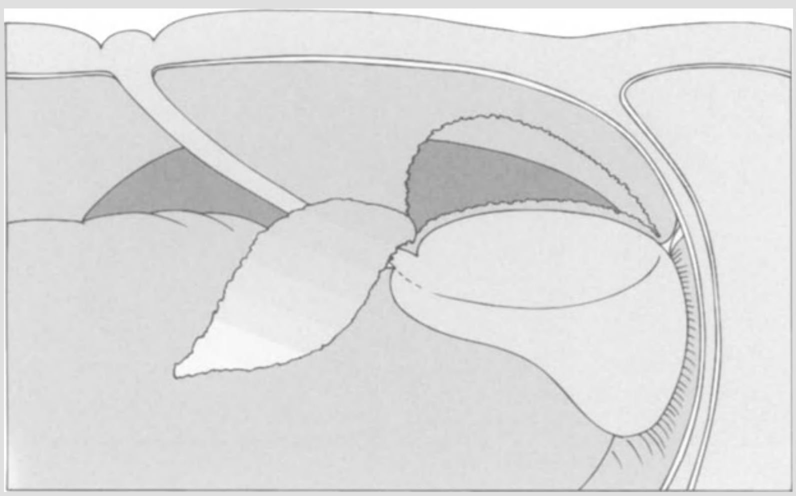


23.8

Fig. 23.7. Vascular anatomy of the ligamentum teres/falciform ligament complex. The separation of the round ligament occurs along the *dotted line.* During the mobilization of the round ligament, the vascular arcade alongside it derived from the hepatic vessels must be preserved

Fig. 23.8. Division of the peritoneal window above the liver. This is undertaken from the left side after tenting and fixation of the peritoneum by the assistant using a palpating probe introduced from the right side

suprahepatic arcade. Fine vessels traverse the window to terminate superiorly in the suprahepatic arcade and inferiorly into the serosal vasculature covering the liver. Below the liver, the two peritoneal leaves are separated by a fatty layer of variable thickness which always contains large veins.

The mobilization must proceed along a set plan to ensure preservation of the blood supply to the teres ligament. The path of the dissection is outlined by the stippled line in Fig. 23.7.

1. Separation starts in the transparent window in the falciform ligament below the suprahepatic arcade using electrocautery and scissors division along the margins of the window leaving a 0.5-cm cuff on the superior surface of the liver. This separation is performed from the left side after tenting and fixation of the peritoneum by the assistant using a palpating probe introduced from the right side (Fig. 23.8). Posteriorly, it is important that the peritoneum is divided as far as the diaphragm in the region of the suprahepatic vena cava. This division allows the liv-

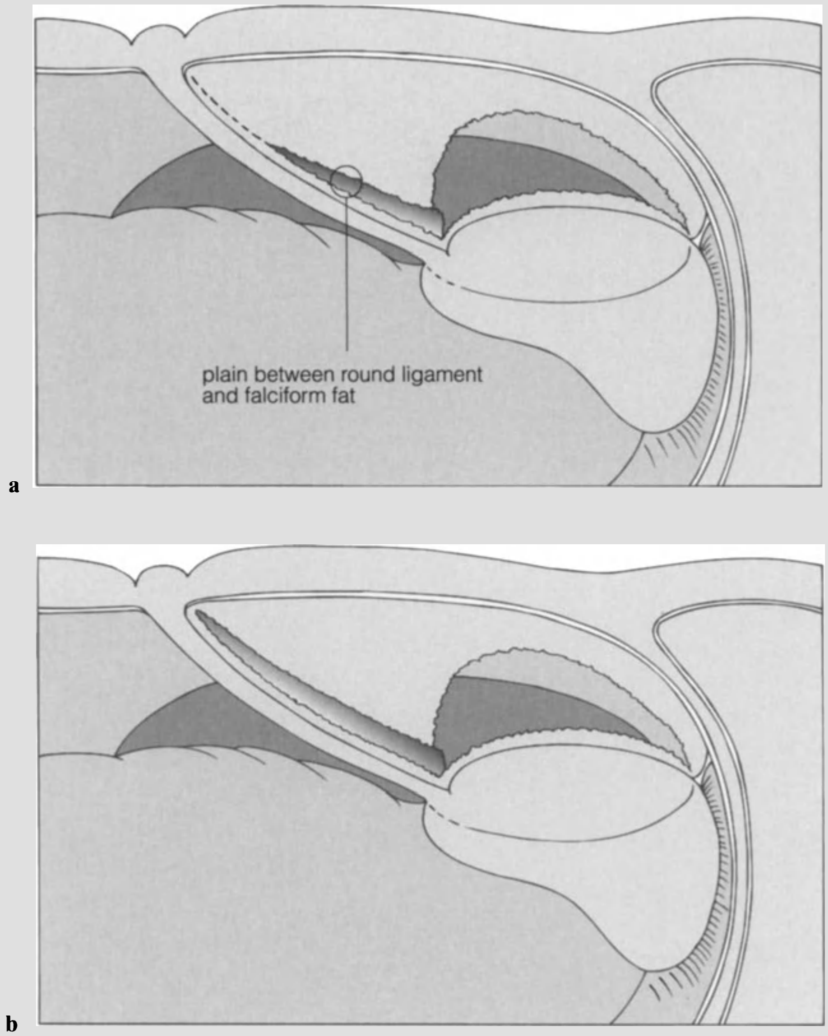
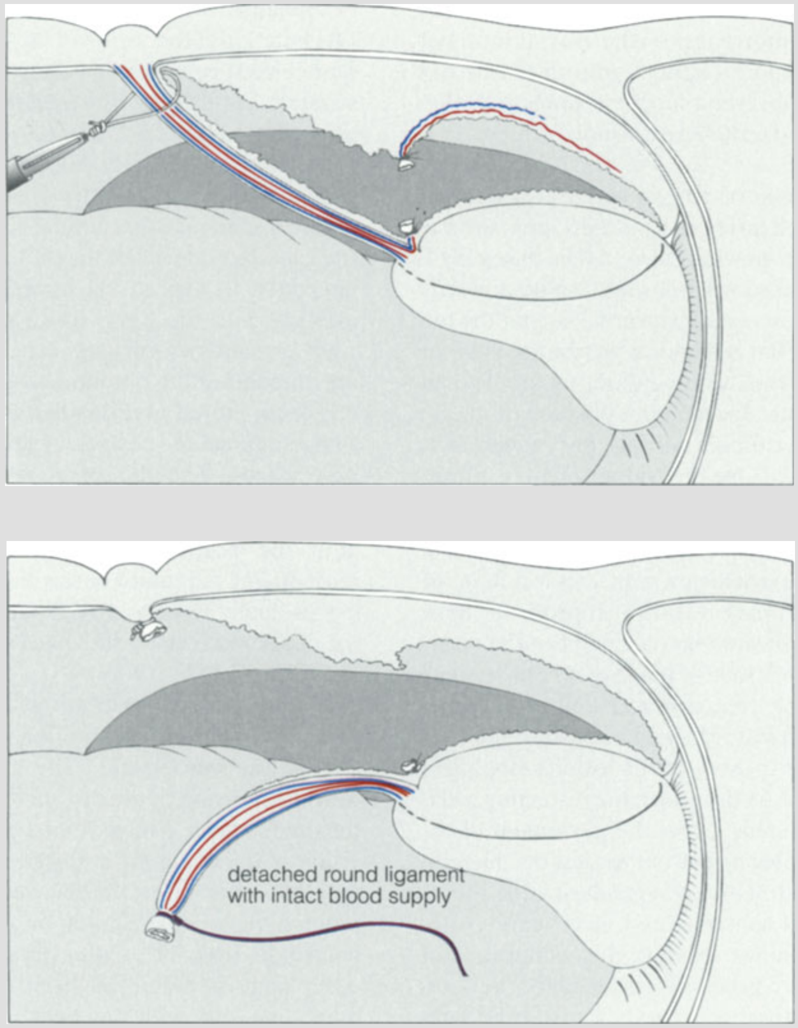


Fig. 23.9. **a** The peritoneum on the left side of the falciform is divided parallel and close to the teres ligament, but well away from its vascular supply up to the umbilical insertion of the ligament. **b** The teres ligament is then separated from the falciform fat by careful blunt dissection of the areolar tissue plane between the falciform fat and the teres ligament

er to sag down, thereby enhancing the effective reach of the teres ligament. Incomplete division of this peritoneal fold will result in insufficient length of the mobilized teres ligament to enable an effective long sling capable of being sutured to the anterior wall of the stomach.

2. The peritoneum on the left side of the falciform is divided by cutting electrocautery or scissors parallel and close to the teres ligament but well away from its vascular supply. This peritoneal division is continued up to the umbilical insertion of the teres ligament (Fig. 23.9a).
3. The round ligament is then separated from the falciform fat by careful blunt dissection using the closed scissors or the heel of the L-shaped electrosurgical knife. There is a well-established areolar tissue plane between the falciform fat and the teres ligament and its blood supply (Fig. 23.9b). If the dissection is kept within this plane, the separation is easy and bloodless. Furthermore, the veins traversing the falciform fat can be identified and electrocoagulated. In obese patients, when the falciform ligament is heavily fat laden, this separation and the identification of vessels which require electrocoagulation can be facilitated by transillumination. This is achieved by introducing a second telescope connected to a light source to transilluminate the falciform apron from the right side. During this manoeu-



a

b

Fig. 23.10. **a** After complete separation from the falciform fat, the teres ligament is still attached at its origin from the umbilical fissure of the liver and insertion into the posterior aspect of the umbilicus. **b** The proximal ligature is left along. This is used as a "tow rope" to pull the ligament around the oesophagus at a later stage

vre, the light to the camera/telescope assembly has to be dimmed.

4. The two preceding steps are repeated on the right side by the assistant. For this purpose the camera/telescope unit is transferred to the right side. On completion, the round ligament is seen to be separate from the falciform fat but is still attached at its origin from the umblical fissure of the liver (from which it derives its blood supply) and at its insertion into the posterior aspect of the umbilicus (Fig. 23.10 a).
5. The insertion of the teres ligament into the umbilicus is then cleared of surrounding tissues and is doubly ligated in continuity with catgut (Roeder knotting) and divided. The proximal ligature is left long. This is used as a "tow rope" to pull the ligament around the oesophagus at a later stage (Fig. 23.10 b).
6. The raw area on the anterior abdominal wall, falciform fat and diaphragm is inspected for haemostasis and any bleeder electrocoagulated or clipped.

Mobilization of the Abdominal Oesophagus and OG Junction

Exposure of the region is obtained by lifting the left lobe of the liver. Although this step can be performed by continued lifting of the left lobe by the expanding retractor rod, this is not ideal and leads to some trauma with subserosal haemorrhages on the liver surface. For this reason, the endoretractor is introduced at this stage. Apart from obviating surface trauma to the liver, it provides an unparalleled exposure.

1. The telescope/camera unit is withdrawn and the telescope inserted inside the endoretractor as far as the centre of the viewing cut-out. The assembly is then turned upside down (viewing section upwards, light cable of telescope downwards) so that the terminal retracting bar assumes a horizontal position in line with the rest of the endoretractor. The assembly is then introduced in this position inside the 11.5- or 12.0-mm cannula until the peritoneal cavity is reached. At this stage the endoretractor is turned to its operating position (viewing section downwards) and the light cable of the 30° forward-oblique telescope is held upwards. This results in the retracting rod flipping down in front of the optic without any significant encroachment of the visual field. Whilst the left lobe of the liver is held lifted up by the expanding retractor rod, the endoretractor/telescope unit is advanced underneath the liver giving excellent exposure of the lower oesophagus and OG junction. At this stage, the retracting rod is removed. The system allows the movement of the optic inside the viewing cut-out to alter the magnification of the field. If at any stage during the procedure the optic is contaminated, it is simply withdrawn for cleaning, leaving the endoretractor behind. The above process is reversed for the withdrawal of the endoretractor at the end of the operation.
2. The important landmark to the right lateral margin of the oesophagus is the anterior nerve of Latarjet near its origin. The peritoneum is grasped to the left of the anterior nerve of Latarjet and divided with scissors medial to the nerve along the right margin of the oeseophagus. It is important to keep the dissection high, well cephalad to the left gastric vessels. At this level, only a few small veins cross the oesophagus and require electrocoagulation before division.
3. The next step consists in the exposure and delineation of the margins of the hiatus. The peritoneum over the anterior margin is divided, and by blunt dissection, preferably with the pledget swab, the hiatal margin is separated from the front and sides of the oesophagus. The blunt dissection by pledget swab is carried out in an upward direction to tease the peritoneal lining and the phreno-oesophageal membrane from the anterior vagus and wall of the oesophagus. A few vessels near the left side of the OG junction in the region of the nerves of Grassi require electrocoagulation before they are divided by scissors. At this stage, the margin of the right crus is also exposed (Fig. 23.11 a).
4. Dissection of the right margin of the abdominal oesophagus proceeds with pledget and variable curvature pseudoelastic spatula dissection to expose the right lateral wall of the gullet. The dissection is deepened to expose the lower part of the mediastinum, and the loose tissue plane between the right crus and oesophagus is opened until the lower attachments of the phreno-oesophageal membrane are encountered and divided with scissors. When first identified, the posterior vagus is attached to the oesophagus. The dissection is continued by the curved pseudoelastic spatula medial to this nerve until the posterior wall of the oesophagus is reached, the curvature of the dissecting spatula being gradually increased by progressive extrusion as the dissection reaches the space behind the oesophagus (Fig. 23.11 b).
5. The direction of the endoretractor and telescope is then adjusted to expose the OG junction and the left side of the oesophagus. The gastrophrenic peritoneal reflection is divided, and the upper part of the fundus close to the oesophagus is mobilized. Division of the upper short gastric vessels is unnecessary. However, a few phrenic vessels to the fundus require electrocoagulation or clipping (if large) before division. Thereafter, the left margin of the oesophagus is mobilized from the left crus using blunt dissection with a pledget swab and continued in a downward and posterior direction until the posterior wall of the oesophagus is reached (Fig. 23.11 c). One or two phrenic vessels posterolateral to the gullet are often encountered and can cause bleeding, but haemostasis can be achieved by grasping the bleeder prior to electrocautery.
6. The left subcostal 5.5-mm cannula is replaced by the flexible one. This is achieved quickly and safely by inserting a 5.0-mm rod prior to removal of the metal cannula and then guiding the flexible cannula over the rod into the peritoneal cavity. The long curved graspers are introduced through the flexible cannula and passed long the posterior wall of the oesophagus from the right side until they emerge to the left of the OG junction. The jaws are opened to grasp a vascular silicon sling introduced by straight graspers through a small stab wound high up in the left hypochondrium (Fig. 23.11 d). The sling is pulled around the gullet by careful withdrawal of the curved graspers, and, following transfer to the

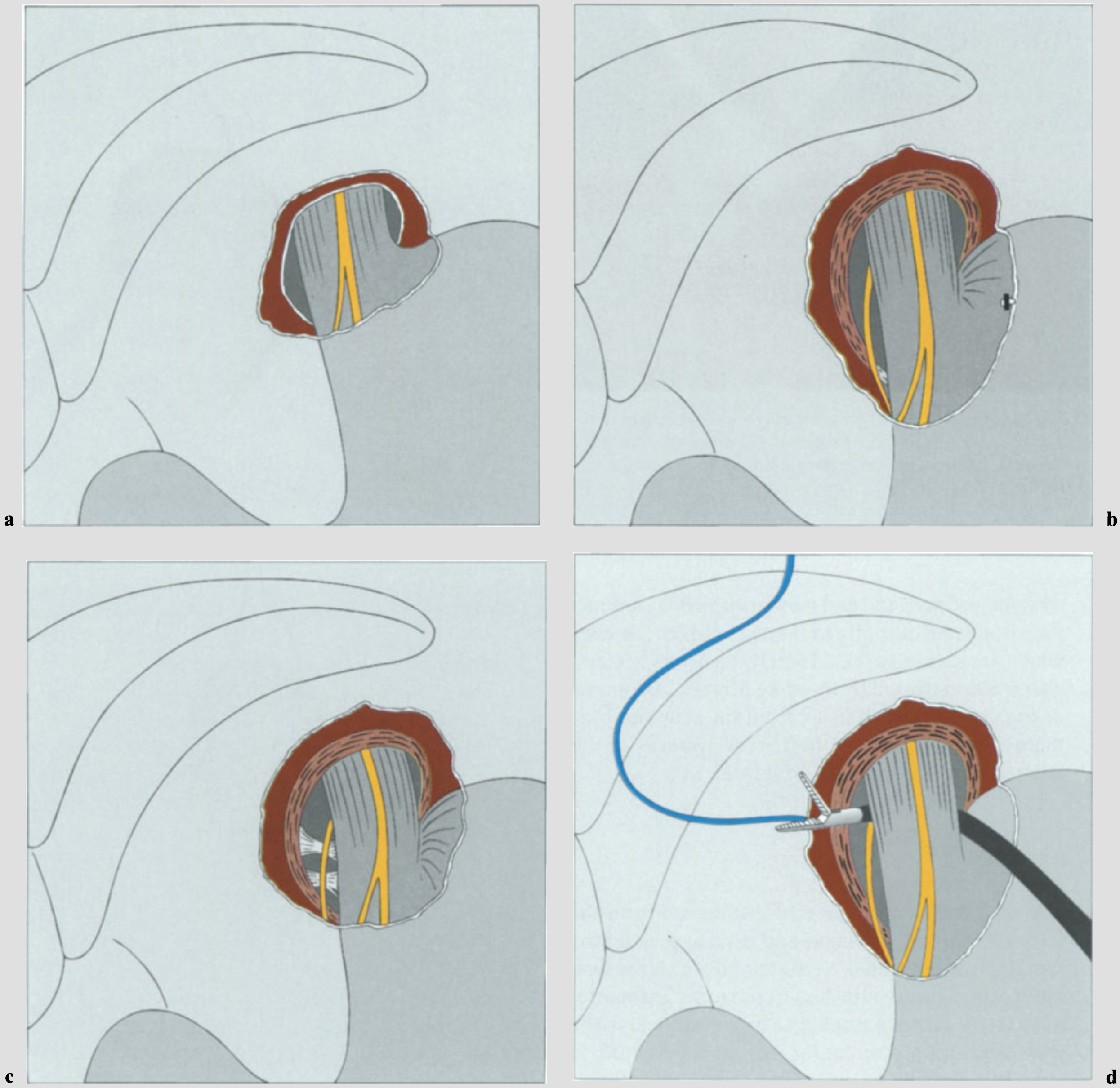


Fig. 23.11. **a** Exposure and delineation of the margins of the hiatus. The peritoneum over the anterior margin is divided, and the hiatal margin is separated from the front and sides of the oesophagus by blunt dissection. **b** Exposure of the right lateral wall of the gullet. The dissection is deepened to expose the lower part of the mediastinum, and the loose tissue plane between the right crus and oesophagus is opened until the lower attachments of the phreno-oesophageal membrane are encountered and divided with scissors. The dissection is continued medial to the posterior vagus nerve. **c** Mobilization of the left side of the oesophagus. The gastrophrenic peritoneal reflection is divided, and the upper part of the fundus close to the oesophagus is mobilized. Thereafter, the left margin of the oesophagus is separated from the left crus by blunt dissection. **d** The long curved graspers are introduced through the flexible cannula and passed along the posterior wall of the oesophagus from the right side until they emerge to the left of the OG junction. The jaws are opened to grasp a vascular silicon sling introduced by straight graspers through a small stab wound high up in the left hypochondrium. The sling is pulled around the gullet by careful withdrawal of the curved graspers

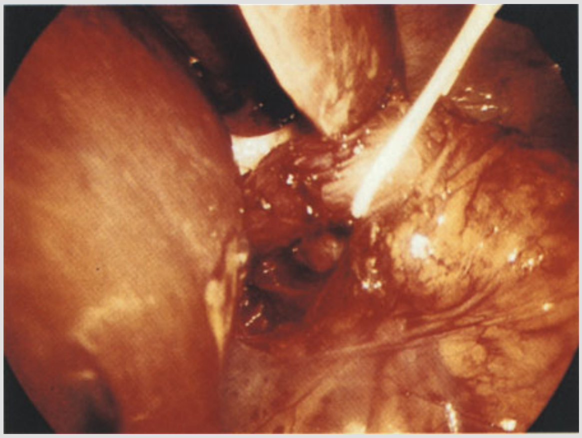


Fig. 23.12. Silicon vascular sling around the oesophagus. Traction on the sling lifts the oesophagus off the crura and hiatus enabling completion of the posterior mobilization by pledget dissection

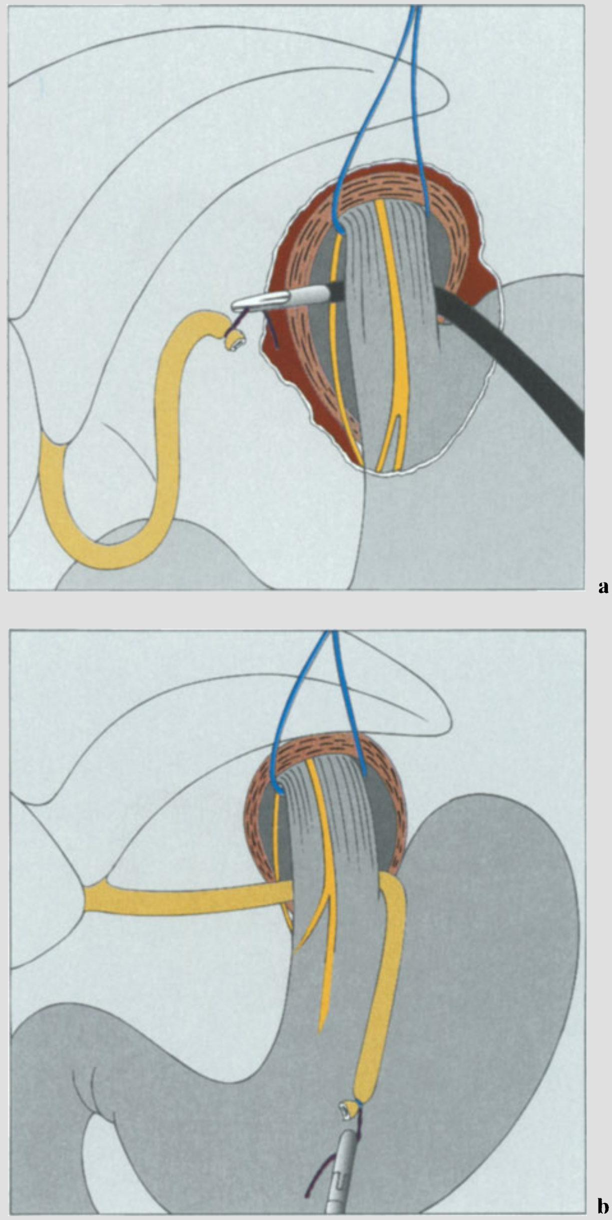
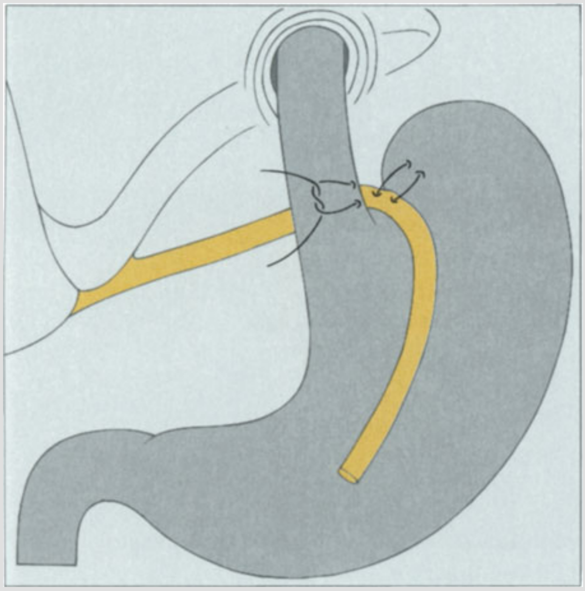


Fig. 23.13 a, b. Re-routing the ligamentum teres. **a** The curved graspers has been passed from the left side behind the oesophagus to emerge along its right margin. The end of the catgut ligature on the teres ligament (tow rope) is grasped and then withdrawn behind the oesophagus when it is transferred to a straight graspers and the curved instrument withdrawn. **b** During this process, the teres ligament is grasped and fed into the retro-oesophageal space to ensure that the traction on the ligature, which must not be excessive, does not strip the vascular coverings of the ligament. The process is continued until there is no slack in the teres ligament sling between its origin from the umbilical fissure and its point of inflexion around the left side of the OG junction

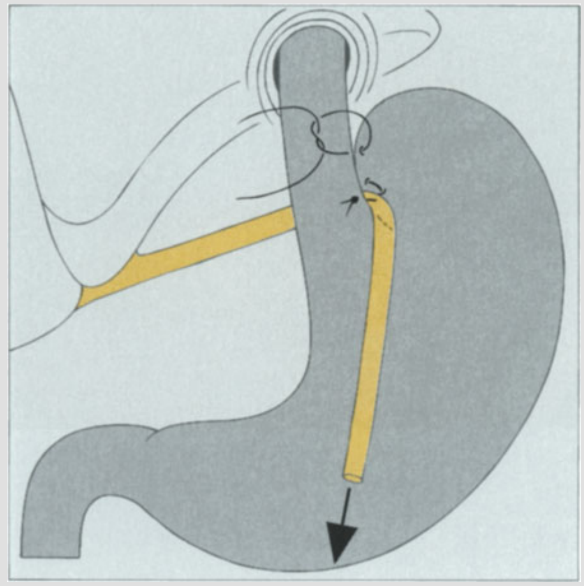
straight graspers, the end is exteriorized. Traction is then applied externally to the two ends of the sling which are secured at skin level by an artery forceps. The traction caused by the sling lifts the abdominal oesophagus forwards away from the crura and the hiatus and allows completion of the posterior mobilization by pledget dissection (Fig. 23.12).

Cardiopexy

1. The long curved grasper is re-introduced from the left side of the oesophagus and used to pick up the long ligature attached to the mobilized teres ligament. The ligature attached to the teres ligament is passed behind the oesophagus by withdrawal of the curved grasper. The catgut lead is transferred to straight graspers and pulled as a "tow rope", thereby guiding the teres ligament around the back of the oesophagus and left side of the OG junction (Fig. 23.13 a). During this process, the teres ligament is grasped and fed into the retro-oesophageal space to ensure that the traction on the ligature, which must not be excessive, does not strip the vascular coverings of the ligament. The process is continued until there is no slack in the teres ligament sling between its origin from the umbilical fissure and its point of inflexion around the left side of the OG junction (Fig. 23.13 b).
2. The end of the ligament is then grasped and pulled down the anterior wall of the stomach along the line of the oblique fibres. The degree of traction influ-



a



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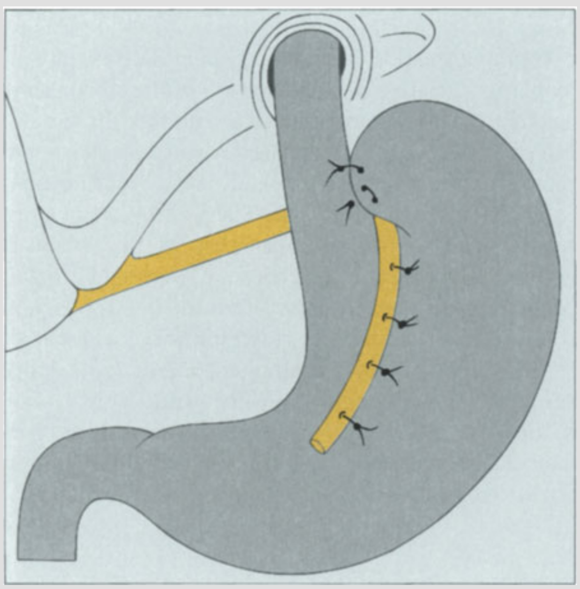


c

Fig. 23.14. a The first suture anchors the teres ligament to the OG junction on the left side and is of the mattress type. **b** The fundus of the stomach is sutured to the adjacent oesophagus above the apex of the sling. **c** Four to six sutures are then used to fix the rest of the teres ligament to the anterior wall of the stomach

ences both the length of the intra-abdominal segment and the pressure within the lower oesophageal sphincter. This is adjusted by oesophageal manometry with zero calibration corresponding to the gastric pressure. The traction on the teres ligament is adjusted to achieve a pressure increment of 15–20 mmHg. This traction is then maintained throughout the rest of the procedure.

3. Suturing is performed using 3/0 black silk sutures and the two-needle holder technique with internal knotting. Each atraumatic suture must not exceed 10.0 cm in length.
4. The first suture anchors the teres ligament to the OG junction on the left side and is of the mattress type. The stitch picks the stomach, ligament and adjacent oesophagus before the needle is reversed and passed again through the ligament and the gastric wall. When tied, this suture fixes the apex of the sling in the intended position (Fig. 23.14 a).
5. The fundus of the stomach near to the accentuated gastro-oesophageal angle (of His) is sutured to the adjacent oesophagus above the apex of the sling (Fig. 23.14 b).


a

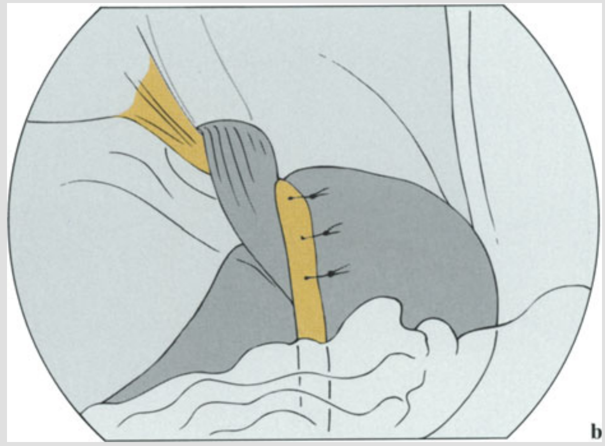

b

Fig. 23.15 a, b. Completed cardiopexy. **a** Endophoto; **b** drawing for interpretation

6. Four to six sutures are then used to fix the rest of the teres ligament to the anterior wall of the stomach along the line of the oblique fibres (roughly parallel to the lesser curve) over a distance of 5–6 cm (Fig. 23.14 c). The appearance at the end of the operation is shown in Fig. 23.15.

Peritoneal Toilet and Closure of Wounds

The operative region and adjacent gutters are irrigated with warm heparinized saline and cleared of any blood and tissue debris. Fluid and blood is likely to accumulate in the left subdiaphragmatic region around the spleen. The accessory cannulae are withdrawn and the stab wounds inspected for bleeding from the inside before the laparoscope is withdrawn and the pneumoperitoneum desufflated. The wounds are then infiltrated with bupivacaine and the skin edges approximated with subcuticular Dexon. The urinary catheter is removed at the end of the operation.

Partial (Toupet) Fundoplication – Operative Details

Types and Placement of Trocar and Cannulae

These are identical to that used for the ligamentum teres cardiopexy (Fig. 23.6).

Mobilization of the Abdominal Oesophagus and OG Junction

Mobiliziation is similar to that previously described, except that the posterior dissection of the oesophagus by pledget swab after the insertion of the silicon sling has to be more extensive to accommodate the fundus. For the same reason, the posterior vagal trunk is separated from the right posterolateral wall of the oesophagus over a greater distance. The gastrophrenic peritoneum medial to the upper pole of the spleen is divided with scissors. Several small vessels, branches of the inferior phrenic artery, require electrocoagulation. If necessary, the first short gastric vessel is cut after the application of titanium clips. Adequate exposure of both crura is essential. The transparent section of the lesser omentum covering the caudate lobe (pars flaccida) is divided high up after ensuring that there is not an anomalous hepatic artery coursing through it.

Fundal Transfer

A curved grasper is passed under the mobilized oesophagus from the right side and used to pick up the fundus of the stomach (Fig. 23.16). This is then gently withdrawn behind the oesophagus to emerge on the right side between the vagus posterolaterally and the OG junction anteromedially (Fig. 23.17).

Creation of the Toupet Partial Wrap

The first row of interrupted sutures (four) attaches the apex of the fundal wrap to the right lateral margin of the anterior wall of the oesophagus (Fig. 23.18). They

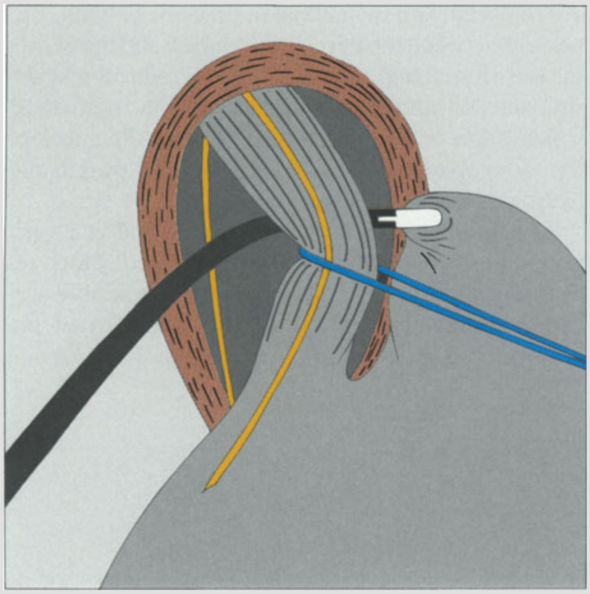


Fig. 23.16. A curved grasper passed behind the mobilized oesophagus is used to pick up the fundus

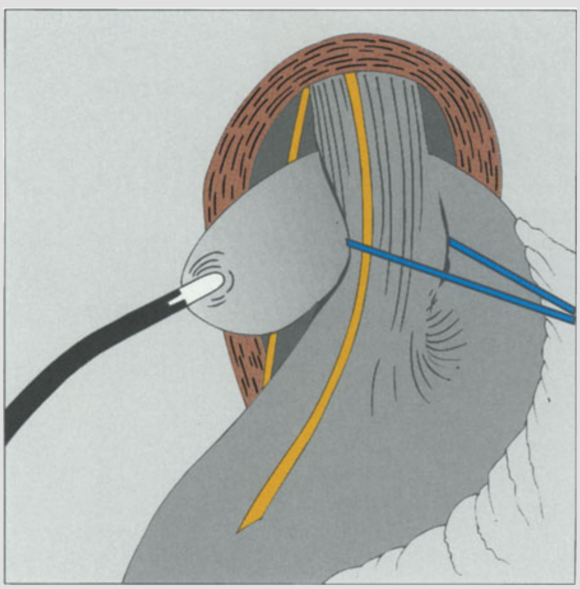


Fig. 23.17. The fundus of the stomach is then gently withdrawn behind the oesophagus to emerge on the right side between the vagus posterolaterally and the OG junction anteromedially

Fig. 23.18. Creation of the Toupet partial wrap which is fixed to the right crus of the diaphragm

are fashioned with 3/0 black silk and each picks up adequate bites of the stomach and adjacent oesophagus. The lowest of these sutures fixes the wrap to the OG junction.

The second row of sutures (two-three) on the right side attaches the fundus further back to the left crura of the diaphragm (two sutures 18 each crus). Again, good bites are taken. The parenchyma of the caudate lobe often requires elevation as the needle is passed through the crus.

Finally, the stomach to the left side of the oesophagus is sutured to the anterolateral wall of the oesophagus by a further four interrupted sutures, ensuring that the oesophageal bites do not pick up the anterior vagus nerve (Fig. 23.18).

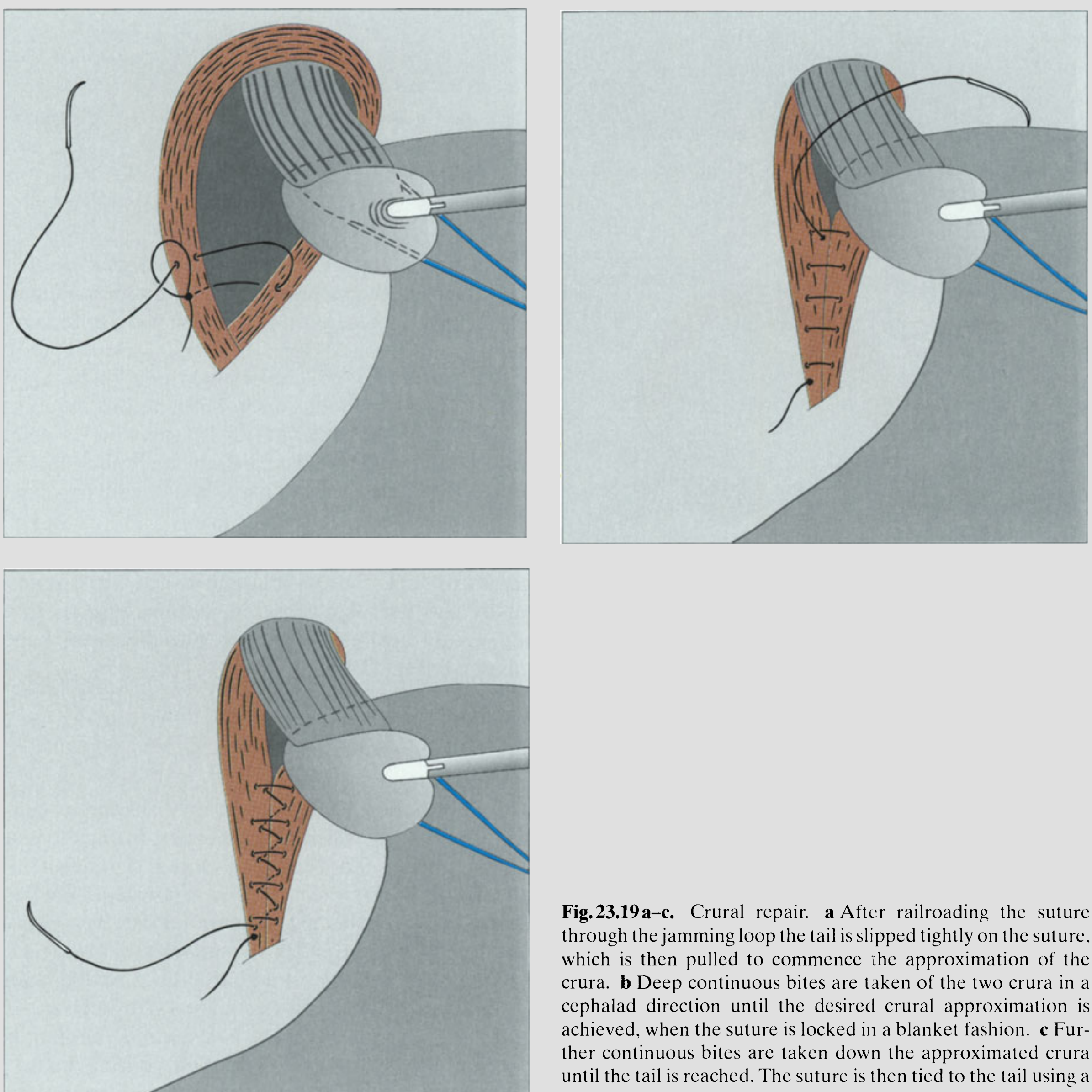
Postoperative Care

The nasogastric tube is removed after recovery of consciousness. A chest X ray is neccessary during the first 6 h as a pneumothorax may develop. If significant, an underwater seal intercostal drain is inserted. Oral fluids are started on the 1st postoperative day. Postoperative ileus is unusual, and most patients are able to take solid food by the 2nd postoperative day. Shoulder pain is usually experienced during the first 12 h and is treated by intramuscular opiates. Nausea and vomiting is encountered in 20 %–30 % of patients during the first 24 h and may require medication with anti-emetics.

Laparoscopic Reduction, Crural Repair and Total Fundoplication for Large Hiatal Herniae

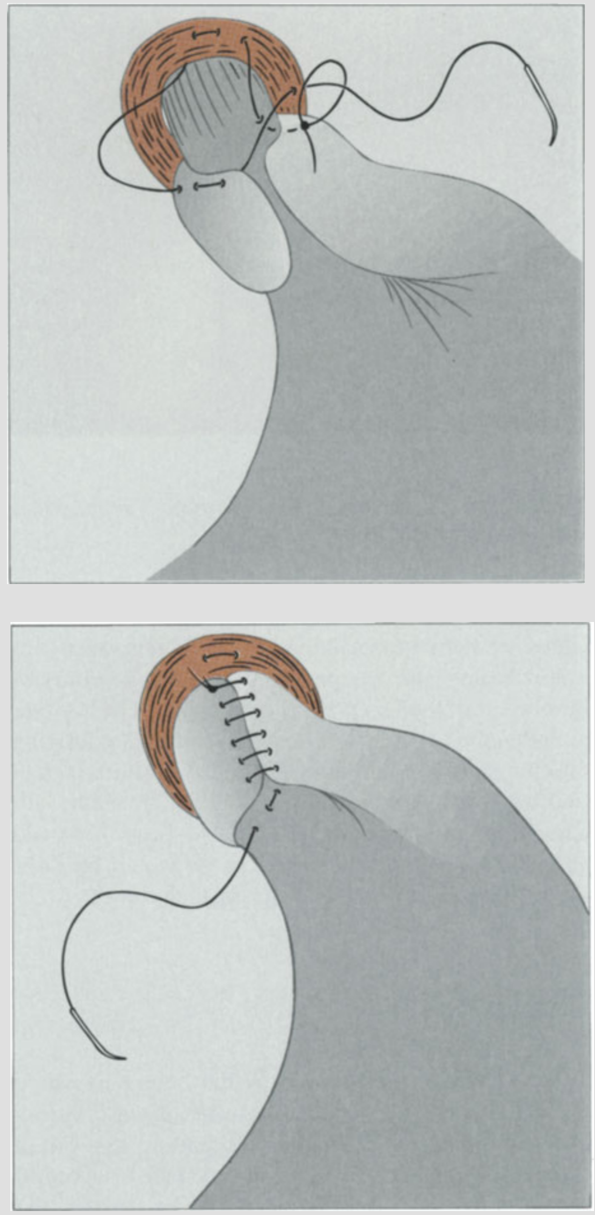
The reduction of the hernia is achieved by a "walking" technique using two grasping forceps. As the uppermost part of the anterior wall of the stomach is grasped and pulled down, the more proximal stomach which appears outside the hiatus is grasped by the second forceps and again pulled down, the process being repeated until the OG junction and distal oesophagus are replaced with the abdomen. In some patients, adhesions between the herniated stomach and the hernia sac are present and require complete reduction of the stomach. No attempt is made to dissect the hernia sac, which is left behind in the mediastinum. The neck of the sac is divided by scissors at the hiatal margin and over the lower oesophagus.

The mobilization of the oesophagus and OG junction is performed as previously described. More recently, we have used the shape-memory variable curvature pseudoelastic dissector for this step of the procedure. It is introduced between the left crus and



a b c

Fig. 23.19 a–c. Crural repair. **a** After railroading the suture through the jamming loop the tail is slipped tightly on the suture, which is then pulled to commence the approximation of the crura. **b** Deep continuous bites are taken of the two crura in a cephalad direction until the desired crural approximation is achieved, when the suture is locked in a blanket fashion. **c** Further continuous bites are taken down the approximated crura until the tail is reached. The suture is then tied to the tail using a standard microsurgical knot



a

b

Fig. 23.20 a, b. Fundoplication by continuous suture technique using preformed jamming loop. **a** The first bite picks up the fundus to the left of the oesophagus, the anterior surface of the oesophagus, the wrap and anterior margin of the hiatus. See also text. **b** The stomach edges are then approximated to each other over the oesophagus by running seromuscular bites until the OG junction is reached. The last suture includes the two edges of the wrap and the underlying OG junction

the oesophagus near the angle of His and then gently eased behind the oesophagus (as its curvature is increased by extrusion) until its end emerges from the right side between the gullet and the posterior vagal trunk. A silicon sling is then railroaded round the oesophagus and externalized. Traction on the sling lifts the oesophagus forwards from the crura and permits completion of the posterior mobilization to expose the entire length of the two crura and their insertion. A traumatic grasper is next introduced behind the oesophagus and used to pick the fundus of the stomach held in another grasping forceps introduced from the left side. The fundus is pulled behind and along the right margin of the oesophagus. If present, fibrous adhesions between the posterior surface of the stomach and retroperitoneal structures have to be divided to enable the fundus to be brought round without tension.

The crural repair is conducted first. A 10-cm 2/0 black silk suture is used on an endo-ski needle. A jamming loop knot slipping from the tail is fashioned externally and the tail kept long, approx 2.0 cm. The suture is then inserted into the peritoneal cavity inside a suture applicator. The needle is passed through the right and left crura near their insertion and the suture pulled until the jamming loop knot impinges on the lateral aspect of the right crus. The 3-mm needle holder is then passed through the loop to grasp the suture and pull it through the jamming loop (Fig. 23.19 a), the tail of which is slipped tightly on the suture which is then pulled to commence the approximation of the crura. Deep continuous bites are taken of the two crura, progressing in a cephalad direction, until the desired crural approximation is achieved, when the suture is locked in a blanket fashion before the direction of the running stitch is reversed (Fig. 23.19 b). Further continuous bites are taken down the approximated crura until the tail is reached (Fig. 23.19 c). The suture is then tied to the tail using a standard microsurgical knot using the two needle holders. In smaller herniae where the hiatal defect is not too large, the repair is effected by 2–3 interrupted sutures.

In these herniae, we use a total wrap (with a 35-F orogastric tube in situ) and we prefer to perform the fundoplication using a continuous suture technique with 3/0 black silk. Again, a 10-cm suture with a long-tailed jamming loop is used. The first bite picks up the fundus high up to the left of the oesophagus, the anterior oesophageal wall, the uppermost edge of the wrap and the anterior margin of the hiatus, in that order (Fig. 23.20 a). After passage of the needle through the jamming loop, the tail is slipped and the suture is pulled to achieve the approximation of the stomach walls to each other and to the anterior margin of the hiatus. A locking knot (double throw) is made between the suture and the tail to prevent slipping of the approximated stomach walls from each other and the hiatus during the rest of the suturing. The stomach


a

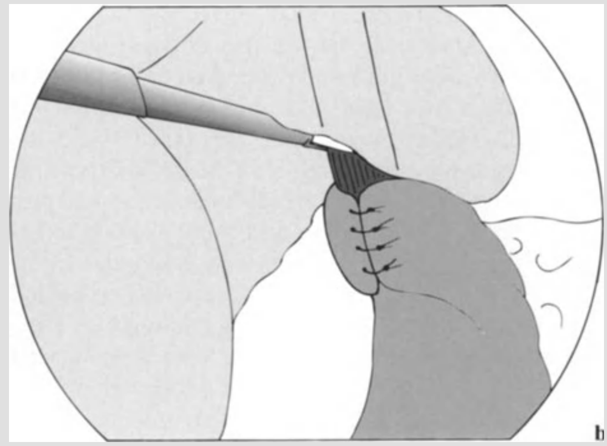

b

Fig. 23.21 a, b. Completed fundoplication. **a** Endophoto; **b** drawing for interpretation

edges are then approximated to each other over (but not including) the oesophagus by running seromuscular bites until the OG junction is reached. The last bite included the two edges of the wrap and the underlying OG junction (to fix the wrap), and the suture is then tied using the Aberdeen knot (Fig. 23.20 b). The silicon sling and orogastric tube are then removed (Fig. 23.21 a, b). Alternatively, the wrap can be fashioned using an interrupted suturing technique.

Clinical Results

Laparoscopic antireflux surgery has been performed on 56 patients with intractable reflux disease during the past 3.5 years. Eight patients had an associated sliding hiatus hernia which required reduction, crural repair and total fundoplication. This increases the technical difficulty of the procedure, particularly the mobilization of the oesophagus and, for this reason, adds to the operating time. The postoperative period has been smooth in all patients with no serious complications and all were discharged by the 7th postoperative day. A pneumothorax may develop after mediastinal dissection. Also mild surgical emphysema is very common.

To date, permanent complete symptomatic relief has been obtained in 54 patients without persistent dysphagia, early satiety or symptoms of the gas bloat syndrome. After ligamentum teres cardiopexy ($n = 12$) one patient developed recurrence of heartburn 6 months after the operation although her postoperative ambulatory pH and endoscopy were normal. Repeat studies with oesophageal manometry, endoscopy, 24-h pH monitoring, isotope transit (^{99m}Tc-labelled solid egg bolus) and barium contrast studies are being performed sequentially on all the patients at varying intervals after the operation.

The results to date have shown that oesophageal transit and 24-h pH monitoring have remained normal. Both the length of the intra-abdominal segment of the oesophagus (below the respiratory inversion point) and the lower oesophageal pressure are significantly elevated when compared to the preoperative values in the ligamentum teres cardiopexy group ($n = 9$). The postoperative appearances on contrast radiology after this procedure are distinctive. There is lengthening of the intra-abdominal segment of the oesophagus due to the depression of the OG junction equivalent to two vertebral bodies and a marked accentuation of the angle of His. Similar lengthening is encountered after the Toupet fundoplication, but the lower oesophageal sphincter pressure has not been significantly different from the preoperative values in these patients.

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24 Laparoscopic Cardiomyotomy for Achalasia

A. Cuschieri, S. M. Shimi, and L. K. Nathanson

Introduction

The cause of the parasympathetic neuropathy in achalasia remains unknown. The treatment of this distressing condition varies from medication with nitrates and calcium-blocking agents, disruption of the lower oesophageal sphincter by balloon dilatation, advocated by gastroenterologists, to surgical intervention. The results of medication with nitrates are indifferent, and the early promise of the value of nifedipine has not be confirmed by prospective studies. Surgical treatment consists of a short 5.0–6.0-cm myotomy which includes the whole extent of the lower oesophageal high pressure zone and adjacent 1.0 cm of stomach. In the only reported prospective study comparing the two techniques, the outcome following myotomy was successful in 95% as compared to 65% after balloon dilatation. Opinions also differ amongst surgeons with regard to the approach: thoracic or abdominal. The disadvantage of open surgical myotomy is the precipitation of gastro-oesophageal reflux, the reported incidence of which varies considerably. However, in a collective review, this complication was found to be more common after abdominal than thoracic myotomy, presumably because the open abdominal approach disturbs the attachments of the lower oesophagus to a greater extent. The way around this persistent controversy is to treat achalasia with endoscopic cardiomyotomy.

Indications and Patient Selection

It is our view that all patients with confirmed achalasia (see below) who are fit for general anaesthesia should be treated with laparoscopic or thoracoscopic cardiomyotomy (see Chap. 11). There is not enough experience to date to compare the outcome of these two approaches. In general, we advocate the laparoscopic approach if the patient has not had previous upper abdominal surgery and the thoracoscopic route if he/she has.

Preoperative Work-up and Preparation

In addition to routine tests aimed at assessing fitness for general anaesthesia and operation, the following investigations are necessary in these patients: upper gastrointestinal flexible endoscopy, barium swallow, oesophageal manometry and oesophageal transit using the radio-labelled solid bolus test. These tests confirm the diagnosis and exclude co-existing organic disease. In particular, manometry will show non-propulsive contractions or aperistalsis and failure of relaxation of the lower oesophageal sphincter in response to dry and wet swallows. The endoscopy must exclude organic disease at the oesophago-gastric (OG) junction. The flexible endoscope should pass with ease through the tonically contracted lower oesophageal sphincter into the stomach.

Anaesthesia

Laparoscopic cardiomyotomy is performed under general anaesthesia with endotracheal intubation. Antibiotic prophylaxis is not administered routinely in these patients. A nasogastric tube is inserted and the stomach is kept deflated. This is essential for the visualization of the abdominal oesophagus and the O-G junction. The patient's urinary bladder is catheterized during the procedure.

Patient Positioning and Skin Preparation/Draping

The patient is placed on the operating table in the supine position with 15°–30° head-up tilt, with the surgeon operating for the most part from the left side of the patient. The skin is prepared with medicated soap (Hibiscrub) and then disinfected with the antiseptic of choice. The area prepared in this fashion extends from the nipple line to the pubis and laterally to the flanks. Draping is similar to that for laparoscopic cholecystectomy. It is important that the entire costal margin is included in the operative field. If a pneumatic laparoscope holder (First Assistant, Leonard, Philadelphia) is used, the unsterile stem is fixed to the rail of the operating table towards the foot and on the left side.

Layout of Ancillary Instruments and Positioning of Staff

The surgery is performed with the surgeon operating from the left side. The assistant and scrub nurse are situated on the right side of the patient. The layout of the ancillary equipment is similar to that used in cholecystectomy. It is essential that a two-monitor visual system is available as the assistant plays a very active role in the dissection of the hiatus to expose the anterior surface of the lower 5.0 cm of the oesophagus and OG junction.

Details of Specific Instruments and Consumables for the Procedure

In addition to the basic instrumentation, the following special equipment is necessary:

1. 10.0-mm 30° forward-oblique telescope (essential for hiatal surgery)
2. Umbrella (expanding) retractor rod (see Chap. 23) or Endoretractor (see Chap. 23)
3. Push rod for Roeder slip knotting in continuity

Operative Steps

The patient is operated on in the supine position. The pneumoperitoneum is established using the Veress needle inserted in the subumbilical region with CO_2 and an electronic insufflator set at a pressure of 13.0 mm Hg. The position of the trocars and cannulae is shown in Fig. 24.1. The laparoscopic cannula (11.0 mm) is inserted first. It is situated 2.5 cm above and to the left of the umbilicus (p1). The other three cannulae are inserted under vision. The 5.0-mm cannula just below and to the right of the xiphoid process is used for the expanding retractor (p4) used to lift up the left lobe of the liver. It can be dispensed with if a dipping endoretractor is used as this retractor is inserted through the same cannula employed for the telescope. The two operating cannulae are situated, one in the lower left subcostal region (p2) (5.0 mm) and the other to the right of the midline midway between the umbilicus and the xiphisternum (p3).

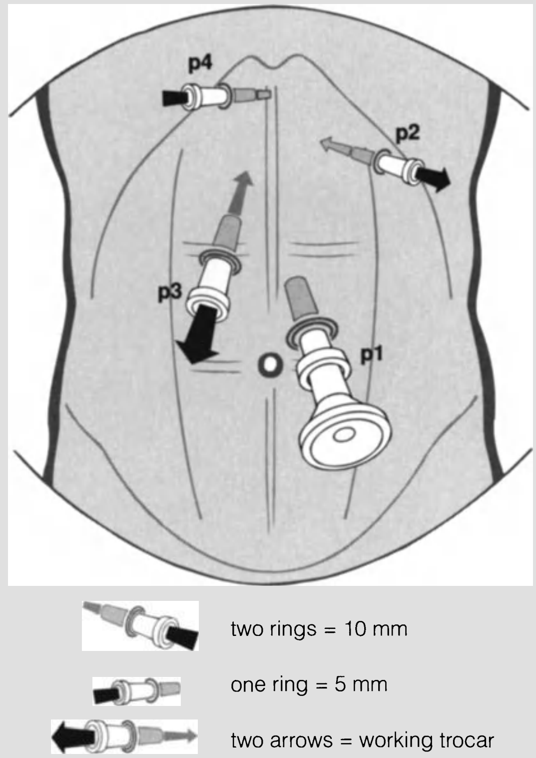


Fig. 24.1. Sites for placement of the trocars and cannulae

Dissection of the Hiatus

The procedure starts with division of the peritoneum over the hiatal margin to expose both crura and the superior rim using twin-action dissecting scissors and electrocautery (Fig. 24.2). The right posterolateral wall of the gullet is then dissected high up above the OG junction by a mixture of blunt (pledget swab) and sharp (scissors and L-shaped hook knife) dissection until the mediastinum is reached. Anchoring bands of the phreno-oesophageal membrane are encountered at this stage. These are preserved, as is the posterior vagus nerve. Anteriorly, the phreno-oesophageal membrane is teased up inside the mediastinum by pledget swab. The anterior vagus nerve is identified at this stage. The left margin of the oesophagus is mobilized from the left crus using a combination of scissors and electrosurgical hook knife dissection. Again, as much of the phreno-oesophageal strands attaching the lower oesophagus to the diaphragmatic canal are preserved.

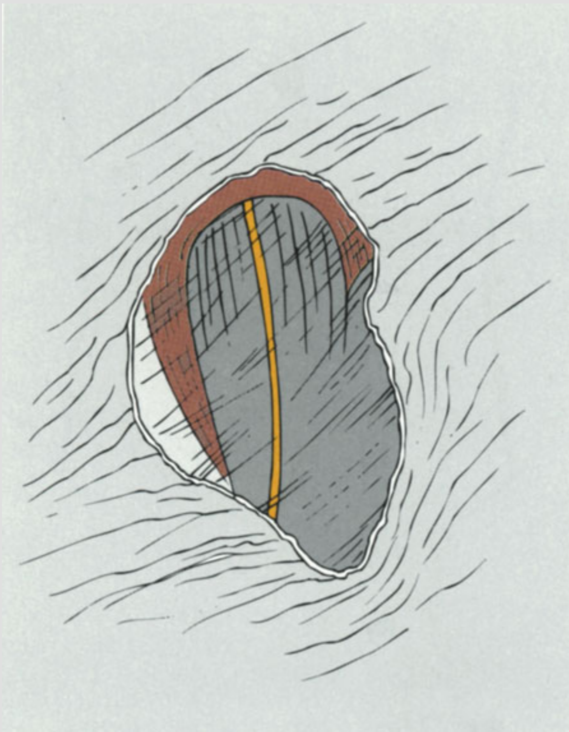


Fig. 24.2. Dissection of the hiatus

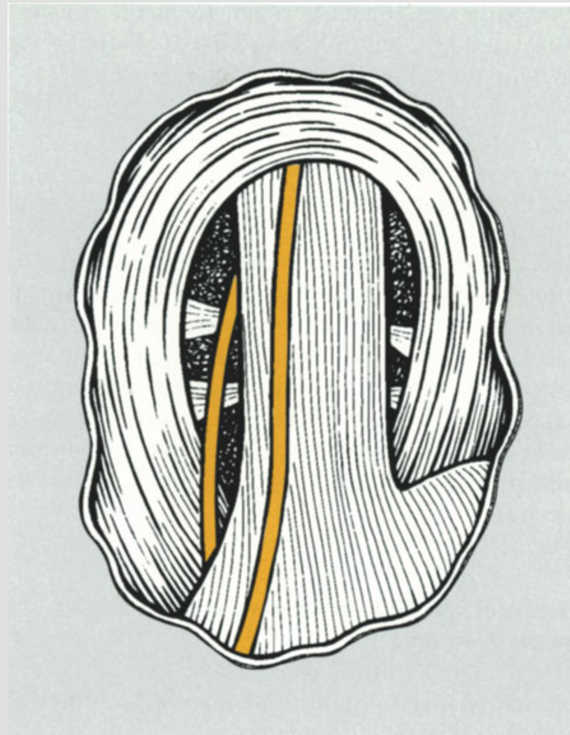


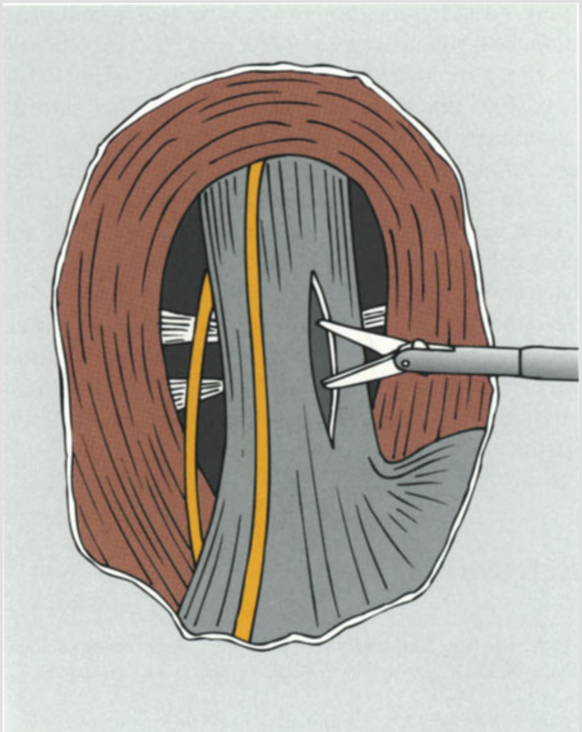
Fig. 24.3. Completed exposure of the anterior surface of the lower 5 cm of the oesophagus and adjacent cardia

Clearance of the OG Junction

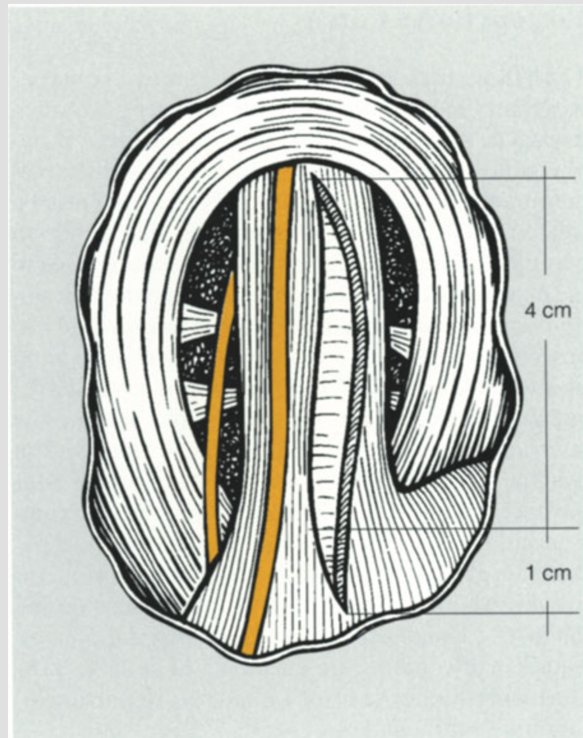
Next, the fat pad on the anterior surface of the gastro-oesophageal junction to the left of the anterior vagus nerve is dissected off the anterior surface of the stomach. This is the difficult step of the operation. Bleeding vessels, mainly veins from the short gastric territory, are often encountered and require control by electrocoagulation or clipping depending on size. This completes the exposure of the anterior surface of the lower 5.0 cm of the oesophagus and adjacent cardia with minimal disturbance to the lower oesophageal fixation (Fig. 24.3).

Cardiomyotomy

The myotomy is started in the middle third of the exposed anterior surface of the abdominal oesophagus to the left of the anterior vagus nerve. It is commenced by superficial electrocautery of the musculature, followed by separation of the muscle fibres by the twin-action scissors until the mucosal coat is reached (Fig. 24.4). Thereafter, the myotomy is extended proximally by use of the electrosurgical hook, ensuring that the muscle layers are separated and tented well away from the mucosal coat before the blended cutting current (40 W) is applied. The distal part of the myotomy must extend over the OG junction to the stomach for a distance of 1.0 cm (Fig. 24.5). The separation of the muscle layers from the mucosa is more difficult to achieve as the submucosal layer of the stomach is less pronounced. A well defined arteriole crosses the OG junction and requires clipping on ligature. Instead of the electrosurgical hook, scalpel division using the microscalpel (reversed hook-knife variety) mounted on a microscalpel holder can be used for this part of the myotomy. This is less likely to cause damage to gastric mucosa, but results in some oozing from the cut muscle edges which is easily controlled by pledged swab compression and, if necessary, superficial diathermy. The appearance of the completed cardiomyotomy is shown in Fig. 24.6. The best technique of establishing that the mucosal layer is intact is to insufflate air via the nasogastric tube after this has been withdrawn into the thoracic oesophagus. If a small perforation is encountered (2 in our experience) this is closed by a single interrupted suture.

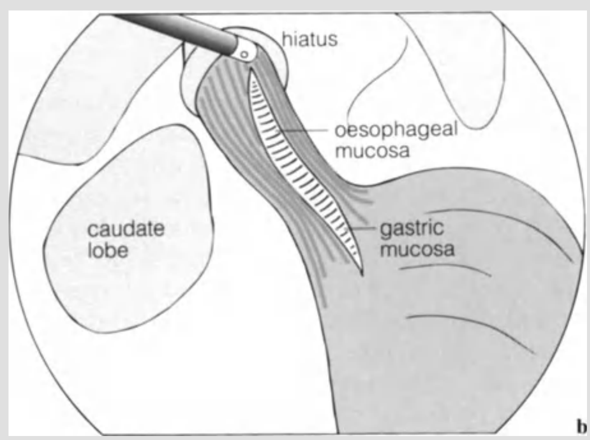


24.4



24.5

24.6a



b

Fig. 24.4. Cardiomyotomy is started in the middle third of the exposed anterior surface of the abdominal oesophagus to the left of the anterior vagus nerve. It is commenced by superficial electrocautery of the musculature, followed by separation of the muscle fibres by the twin-action scissors until the mucosal coat is reached

Fig. 24.5. Extent of the cardiomyotomy. It involves the lower 4–5 cm of the oesophagus and the adjacent 1 cm of the stomach to the left of the anterior vagus nerve. The phreno-oesophageal attachments of the lower oesophagus are largely preserved

Fig. 24.6. Completed laparoscopic cardiomyotomy. **a** Endophoto; **b** drawing for interpretation

Postoperative Care

The nasogastric tube is removed after recovery of consciousness and after a chest X-ray has been performed to exclude pneumothorax. Minor cervical surgical emphysema is common due to CO_2 travelling up the mediastinum. A pneumothorax can occur. It must be treated with suspicion as it may be due either to oesophageal perforation or to inadvertent damage to the pleura. To date, we have not had any patient develop oesophageal perforation after myotomy and endoscopic oesophageal dissection (thoracoscopic or laparoscopic), but there have been two instances of pneumothorax which resolved rapidly following the insertion of an underwater seal drain. A Gastrografin swallow is carried out routinely on the morning after the operation, and, if satisfactory, oral fluids are commenced. Postoperative ileus is unusual, and most patients are able to take solid food by the 2nd postoperative day. Shoulder pain is usually experienced during the first 12 h and is treated by intramuscular opiates. Nausea and vomiting are encountered in 20%–30% of patients during the first 24 h and may require medication with anti-emetics.

Clinical Results

Laparoscopic cardiomyotomy takes an average of 1.5 h to perform. The postoperative period of our 8 patients has been uneventful, and discharge from hospital is usually on the 3rd day. Postoperative assessment to date has confirmed complete relief of dysphagia and no reflux symptoms, but the follow-up has been short (<12 months). The laparoscopically performed procedure has several potential advantages over balloon dilatation and open surgical myotomy. In the first instance, it reduces the trauma of access and permits a much quicker recovery. In addition, the highly magnified field permits a more delicate and controlled myotomy with identification of the vagal trunks and their branches, which are preserved, and reduced damage to the phreno-oesophageal attachment. The latter may be important in the avoidance of gastro-oesophageal reflux which is especially common after abdominal cardiomyotomy and has lead some surgeons to advocate a loose total or Dor partial fundoplication as a prophylactic measure when the open abdominal route is used. This additional procedure may itself cause dysphagia in the presence of an aperistaltic oesophagus. We do not therefore advocate its routine use. The two instances of intra-operative perforation occurred in patients who had had previous balloon dilatation. These patients received a 5 day course of antibiotics after the operation.

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25 Endoluminal Rectal Surgery

G. Buess

Introduction

Colorectal carcinoma develops from a pre-existing adenoma. Regular screening examinations and complete removal of adenomatous precursors help in preventing malignant degeneration. *Sessile adenomas* undergo malignant degeneration frequently and are predominantly located in the rectum and lower sigmoid. The diagnosis is easily established by either rigid or flexible endoscopy. Resections, with the exception of lesions located near the dentate line, have until recently required invasive surgical procedures due to the restricted access to human pelvic anatomy.

In the last few years it has been shown that in selected cases of *early rectal carcinoma,* especially pT1 low-risk carcinoma according to Hermanek, the neoplasm can be excised locally with favorable results.

From 1980 to 1983 we developed the first procedure of ES, specifically for the local resection of tumours, that has been used in general surgery. This procedure required the realization of new principles of optical design, endoscopic instruments, and ancillary units. This progress was being made at the same time that Semm was establishing procedures of operative laparoscopy. The technical and methodological solutions in endoscopic rectal surgery differ in many essential respects from those of laparoscopic surgery and thus must be regarded as a completely separate development.

To differentiate our new technique from the established procedure of operative endoscopy performed via a flexible endoscope, we called the new approach "transanal endoscopic microsurgery" (TEM). The team responsible for this advance, which was made at the Department of Surgery, University Hospital, Cologne, FRG, consisted of Buess, Theiss, and Hutterer.

Indications and Patient Selection

Rectal Tumors

Sessile Adenomas

While gastroenterologists and surgeons performing endoscopy usually remove sessile adenomas up to a diameter of approximately 2 cm with the diathermy snare, the case of larger sessile adenomas located close to the anal verge, a retractor is generally utilized to open up the anal canal. All sessile adenomas remote from the dentate line which can be clearly visualized with a rigid rectoscope and which do not exceed 8 cm in length are suitable for TEM. Resection by this procedure can be extremely difficult in the case of large sessile adenomas located anteriorly in the upper rectum or adjacent to the sigmoid, and inadvertent opening of the parietal peritoneum cannot be avoided in every case. Unless the surgeon has considerable experience with TEM, a low anterior rectal resection is preferable in these difficult situations.

Carcinoma

Four classes of indication can be distinguished:

1. Operations with a high probability of being curative. An example is pT1 carcinoma with good or moderate differentiation without infiltration of lymphatic vessels (low-risk carcinoma according to Hermanek).
2. Operations with a limited probability of being curative. An example is pT2 carcinoma (low-risk carcinoma according to Hermanek).
3. Palliative operation, is in the case of carcinomas up to the T3 stage with good mobility during digital examination and diameters of up to 4 cm irrespective of differentiation.
4. Unsuspected/previously unproven cancers. This is by far the most frequent local cancer operation. Large sessile adenomas contain areas of in situ or invasive carcinomas in up to 20% of cases, and in many cases they cannot be detected preoperatively

by any of the investigations available. These carcinomas are mostly of the pT1 low-risk type, meaning that full thickness excision of the tumor with tumor-free resection margins is most likely to be curative.

The correct selection of patients is an important prerequisite of effective surgery. The full thickness excision technique, which is mandatory in conducting efficient surgical treatment of cancer, is only feasible in the extraperitoneal parts of the rectum: anteriorly approximately up to 12 cm, laterally up to 15 cm, and posteriorly in the case of a very small tumor up to 20 cm from the dentate line.

The data currently available on recurrences subsequent to TEM lead us to believe that the indications are always given for groups 1 and 4 irrespective of age and proximity to the anal sphincter. Class 2 is indicated for old and high-risk patients. Currently the number of patients refusing conventional proctectomy for low rectal tumors is increasing, and they form a new subgroup of cancer patients. In these patients we recommend that for T2 and T3 carcinomas the distal resection margin should be at least 2 cm from the dentate line, so that a coloanal anastomosis can be performed after the excision of the rectum.

We proceed with TEM for group 3 tumors only if the patients are considered to be high-risk candidates.

Transanal Endoscopic Rectopexy (TER) for Rectal Prolapse

This surgical procedure is currently still at an early phase of clinical evaluation. We therefore recommend TER only for patient with a moderate and easily reducible rectal prolapse.

Preoperative Investigations and Diagnostic Procedures

To reliably assess the feasibility of TEM, the surgeon has to perform digital rectal examination, rigid rectoscopy and, if available, endoluminal ultrasonography.

Patient's Medical History in General and of Present Illness

The pertinent questions are outlined in Table 25.1. Questions about preoperative rectal and urinary incontinence are especially important in elderly patients to assess impairment after the intervention.

Table 25.1. Pertinent questions regarding past and present medical history in patients with rectal tumors

Signs and symptoms
Bright red blood per rectum
Passing of mucus
Constipation
Diarrhea
Bowel movements varying in character
Duration of symptoms
Preoperative continence
Incontinent for liquid stool
Incontinent for soft stool
Incontinent for normal stool
Duration of incontinence

Digital Rectal Examination

In approximately half of the patients who can be treated by TEM, the tumor can be palpated. We assess these findings according to Mason's staging.

CSO	soft in texture
CSI	freely mobile
CSII	mobile
CSIII	tethered mobility
CSIV	fixed

For tumors which are soft in texture, such as the typical adenoma, we have added the term "clinical staging zero" (CSO) regardless of the size and mobility.

Rectoscopy

We employ a rigid rectoscope of 18 mm diameter. The macroscopic classification of the polyps is shown in Fig. 25.1.

Adenomas usually exhibit a whitish and villous surface, Even in the case of impalpable tumors, the lesion can be classified as adenomatous-like when the visible part of the lesion can be easily pushed away with the rectoscope. Ulcerated and easily bleeding areas point to the presence of carcinoma.

The exact extent of the polyp is determined by measuring the distance from the anocutaneous line to the upper and lower margins of the tumor (Fig. 25.2). Especially in carcinomas located close to the anal sphincter, the distance from the aboral tumor margin to the dentate line is of further importance. TEM should be performed only when the entire polyp can be well visualized with the rigid rectoscope.

Assessment and documentation of tumor position relative to rectal circumference is of great importance for the correct positioning of the patient on the operating table.

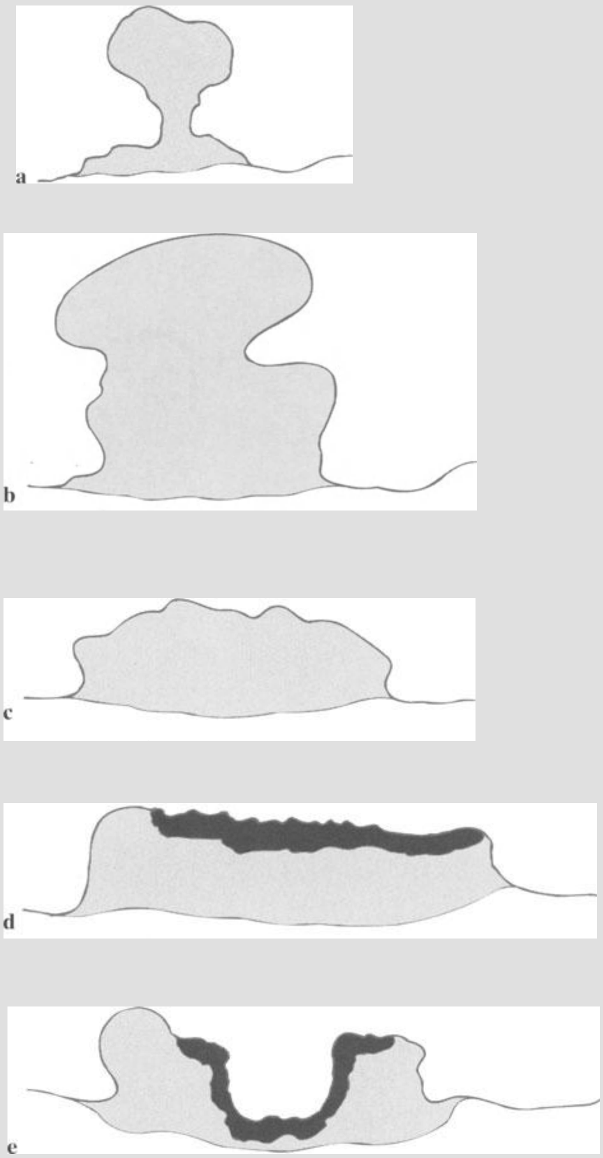


Fig. 25.1 a–e. Endoscopic classification of rectal tumors: **a** pedunculated polyp; **b** broadly pedunculated polyp; **c** sessile polyp, typical for adenoma; **d** sessile polyp, typical for carcinoma; **e** ulcerated polyp, typical for carcinoma

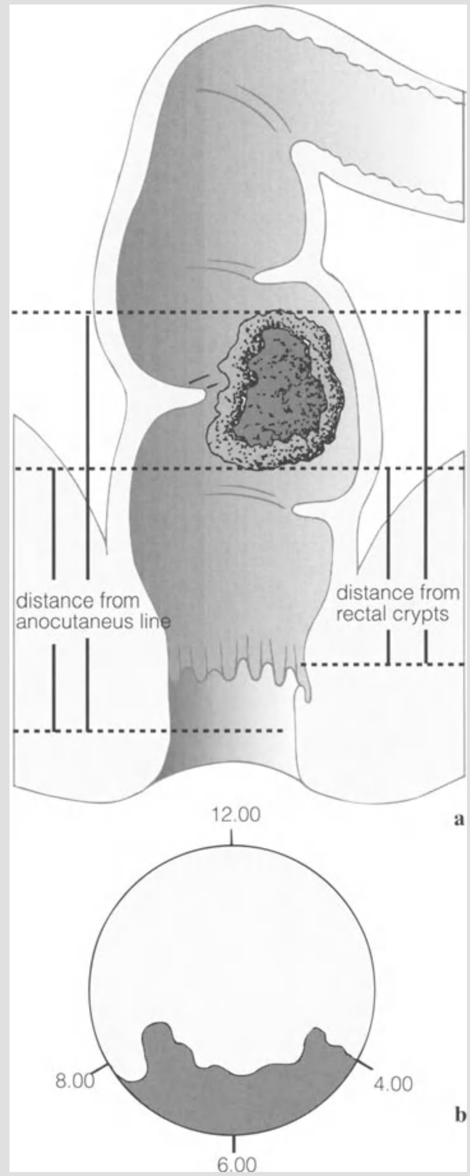


Fig. 25.2 a, b. Endoscopic findings, description of localization. **a** Localizations of height: *left,* distance from anocutaneous line; *right,* distance from rectal crypts. **b** Localization relative to circumference. Descriptions always relative to lithotomy position. The intended intraoperative positioning is explicitly marked preoperatively

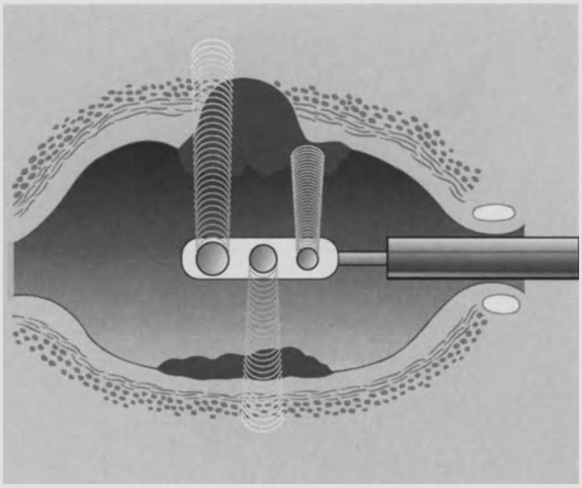
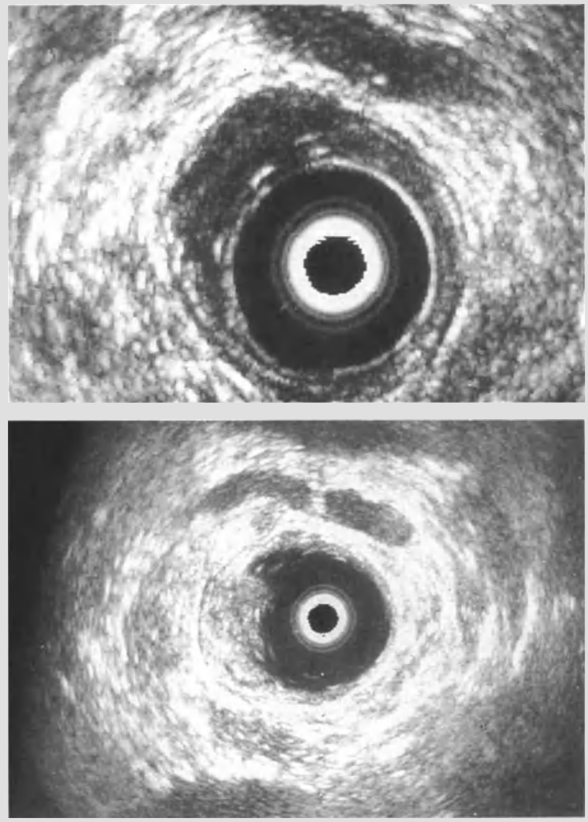


Fig. 25.3. Endoluminal ultrasonography of the rectum with direct water coupling. The exam can be conducted with 5, 8, or 10 MHz scanning probes



25.4 a

b

25.5

Fig. 25.4 a, b. Endoluminal ultrasonography in a patient with adenoma. **a** With water-filled balloon; **b** with direct water filling via the rectoscope

Fig. 25.5. Endoluminal ultrasonography of a T3 tumor with direct water filling via the rectoscope

Endoluminal Ultrasonography

Endoluminal ultrasonography (EU) is the only diagnostic procedure besides digital rectal examination which has demonstrated adequate reliability in assessing the tumor stage. In our experience, the detection of T2 carcinomas in lesions thought to be adenomas is of special significance. A rotating scanner with water-coupling balloon is usually used for staging rectal tumors.

In cooperation with the Kretz company we have developed a new scanning probe. This specially designed rotating scanning probe can be adapted in a watertight fashion to a standard rectoscope. The water-filled rectal cavity then serves as the water-coupling environment. Depending on desired depth of penetration, different scanning transducers of 5, 8, and 10 MHz frequency can be activated (Fig. 25.3). An example of an adenoma with water-coupling balloon is shown in Fig. 25.4 a, and the same specimen with direct water coupling in Fig. 25.4 b. The anatomy of the polyp is better outlined in the water-filled rectum, facilitating the assessment of its base. Figure 25.4 c shows an example of a pT2 carcinoma, and Fig. 25.5 a T3 tumor.

Preoperative Preparation

Informed Consent

The nature of the typical complications after TEM should be explained to the patient by means of a standardized consent form and preoperative interview. The patient should be informed of the possible necessity of revert to the conventional operation if during surgery (a) the polyp cannot be visualized entirely, or (b) safe suturing of the defect is not possible. Other possible complications that the patient must be informed of include:

- Postoperative Bleeding. This requires surgical revision.
- Dehiscence of a Suture Line. This complication is commonly encountered after excision of large polyps causing increased stress on an extensive suture line. The treatment includes temporary parenteral nutrition and, in patients who develop septic complications, a temporary protective colostomy.
- Postoperative Rectal Stenosis. This results from extensive scarring. The treatment is bouginage.
- Transitory Dysuria. This is secondary to mechanical irritation of the urethra during manipulation of the rectoscope and is self limiting.

Bowel Preparation and Preoperative Antibiotic Prophylaxis

Adequate bowel preparation is essential for uncomplicated wound healing. In our experience only orthograde intestinal lavage via a gastric tube with at least 10 l Ringer's solution is sufficiently effective. As a matter of principle we also administer a single dose of an antibiotic combination (metronidazole plus one of the second generation cephalosporins) as preoperative prophylaxis.

Anesthesia

In all ES procedures, intraoperative pain sensations causes uncontrolled movement by the patient and general agitation hindering surgical manipulation. TEM procedures conducted in a prone position or procedures that will take a long period of time are conducted under general endotracheal anesthesia after placement of a urinary catheter.

Patient Positioning and Skin Preparation/Draping

Patient Positioning

The patient is placed depending on the location of the polyp in a prone, lithotomy, or lateral position (Fig. 25.2). The positioning technique on the operating table available in our theaters is shown in Fig. 25.6 a, b. Good padding of the fixation brackets and frames is mandatory. A suitable tilting mechanism enables the surgeon to adjust the operating table to an optimal working position. The Martin arm is attached to the operating table according to the respective position of the patient.

Skin Preparation and Draping of the Patient

Basically, sterile conditions are secured in the same way as in conventional transanal procedures. We clean the perianal skin with an alcoholic solution and omit skin shaving. To isolate the operative area, paper drapes are used. Drapes used for transurethral resections with integrated pouches and openings for connecting tubes are especially suitable for TEM.

Layout of Ancillary Instrumentation and Positioning of Staff

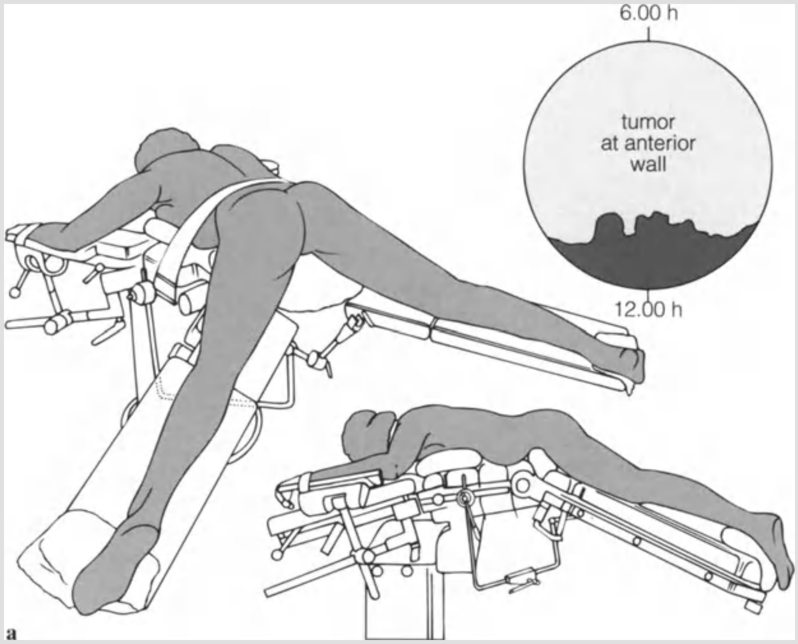
Layout of Ancillary Equipment

The set-up of the theater is shown in Fig. 25.7. The endosurgical combination unit for controlled, automatic gas insufflation and the high-frequency generator is positioned on the left hand side at the foot of the operating table as seen by the surgeon.

The high-frequency generator is controlled via a double footswitch by the surgeon and the optic irrigation via a single footswitch by the assistant. The tube and cord connections are secured to the operating table with tape in a tension-free manner.

A powerful light source is needed and is placed together with the monitor and camera control system on the right hand side of the surgeon.

The U-shaped double-ball joint (Martin arm) is attached to the operating table with the V-groove clamp approximately 20 cm below the anus. This position offers optimal variability and stability of the operating system. Modifications may be necessary if an operat-



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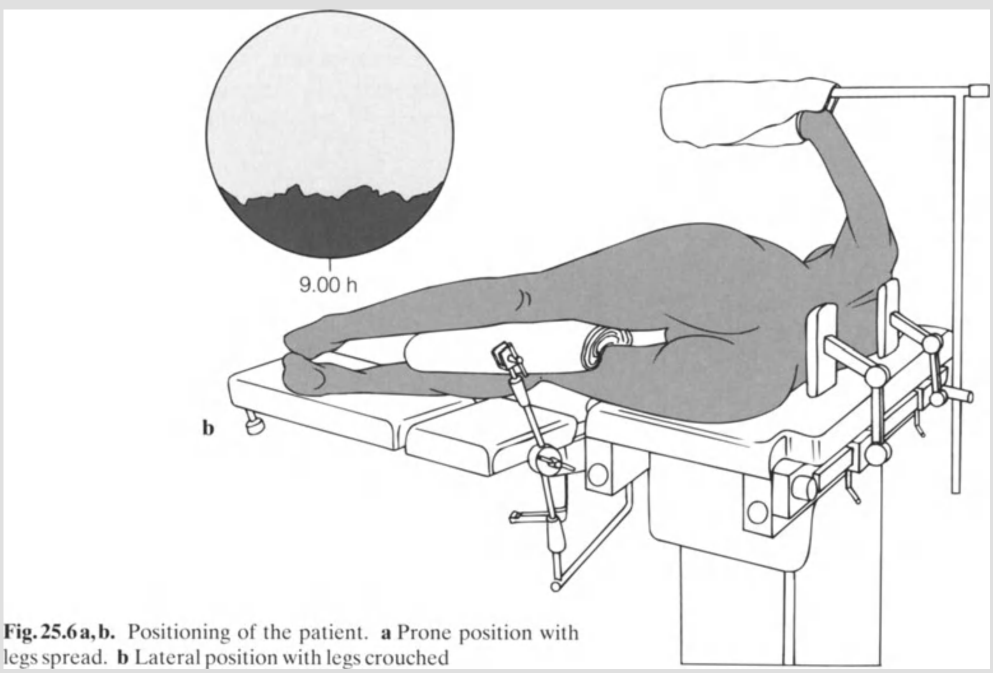


b

Fig. 25.6 a, b. Positioning of the patient. **a** Prone position with legs spread. **b** Lateral position with legs crouched

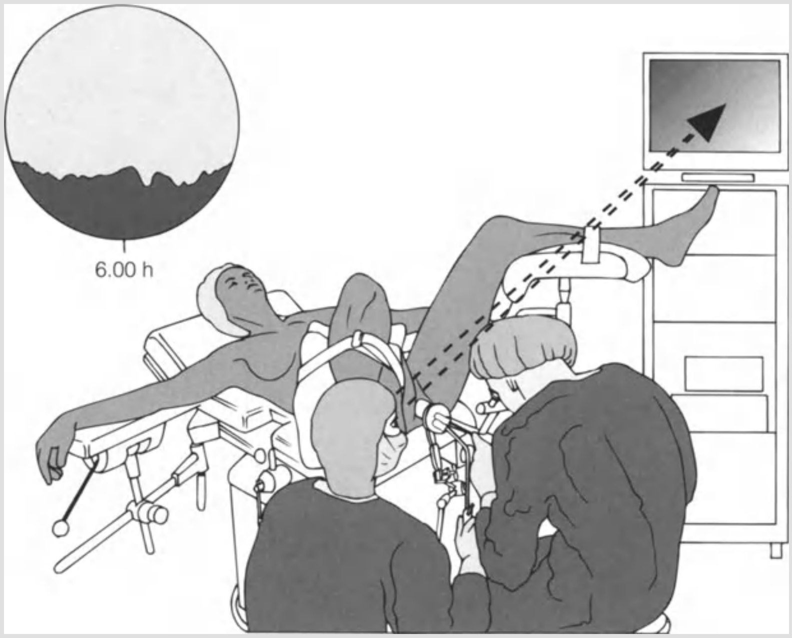


Fig. 25.7. Set-up of theater. The patient is placed in lithotomy position; the surgeon has direct view of the operation area via the stereoscopic optics. The assistant observes the operation via the monitor

ing table different from the one shown in Fig. 25.6 a is used.

Positioning of Staff

The surgeon sits on a vertically adjustable chair with the assistant to his left. The surgeon operates with direct vision via the stereoscopic optics of the operating rectoscope, the assistant with an indirect view via the monitor positioned in his line of vision across the rectoscope.

The scrub nurse sits on the right behind the surgeon, passing instruments laid out on the instrument table from the right.

The Endosurgical Combination Unit

The CO_2 insufflation is operated by pressure control with continuous monitoring of endorectal pressure (Fig. 25.8). The endoluminal pressure is monitored on the rectoscope via the gas pressure gauge channel directly connected to a special fitting. If the endoluminal pressure drops below a predetermined value, automatic insufflation commences at a maximal flow rate of 4 l/min. The use of a conventional suction device for the aspiration of blood and coagulation fumes from the rectal cavity causes a rapid loss of rectal pressure, which leads to a loss of visual control. We therefore utilize a special roller pump with a maximum suction capacity well below the insufflation maximum of the endosurgical combination unit, thus ensuring constant rectal wall dilatation even during maximal suction. The roller pump works continuously, i.e., a gas exchange takes place continuously in the rectal cavity. The suction capacity of the roller pump should only be switched to maximum when blood and coagulation fumes have to be evacuated very quickly as the flow rate of CO_2 from the insufflator would otherwise constantly have to be high, leading to unnecessary loss of CO_2. Another function of the endosurgical combination unit is the rinsing of the optics. Via a luer lock connection of the combination unit, CO_2 at a pressure of 150 mbar is taken from an internal reservoir and brought to an infusion bottle with distilled water. By using a long needle, irrigation fluid is then taken from the bottle to the optics via a second connecting tube passing over a solenoid valve. The assistant, by operating the foot switch, opens the solenoid valve of the combination unit and the irrigation jet is directed toward the front lens.

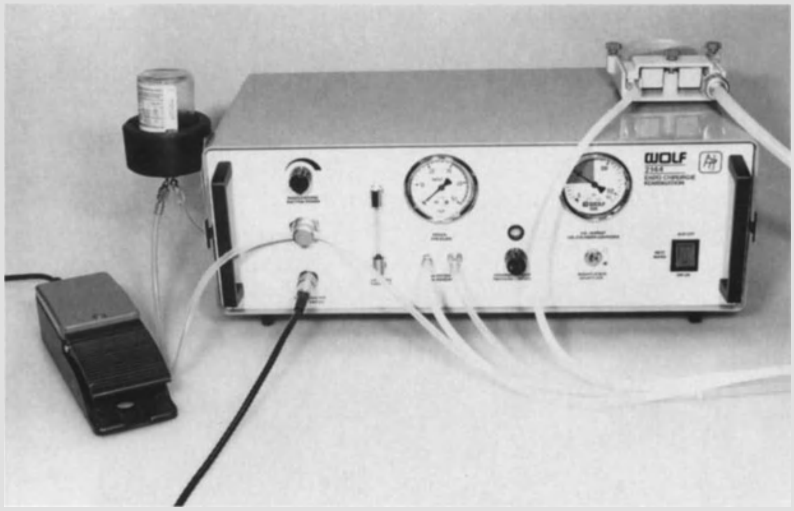


Fig. 25.8. The endosurgical combination unit. Besides channels for measuring intrarectal pressure and gas insufflation, there are additional connections for optic rinsing and suction

Details of Specific Instruments and Consumables Needed for TEM

General Conditions for TEM

The TEM technique is performed via a single access, which means that optics and endoscopic instruments are introduced in the same way. As a consequence, there is limited space for surgical manipulation and the instruments have to run parallel to each other. Since this limitation may easily cause the instruments to obstruct each other during manipulation, increased training is necessary to master the technique manually. The parallel alignment of the instruments and optics precludes a three-dimensional view via a triangulation, and we thus have to use stereoscopic optics.

The Operating Rectoscope (Fig. 25.9 a)

The rectoscope *tube* has an outer diameter of 40 mm and a functioning shaft of either 12 or 20 cm. The tube is connected to the basic element with an integrated handle by a bayonet mounting. The distal end of the tube is beveled. With correct positioning of the optics, there can be no direct contact of the front of the lens with the bowel (see Fig. 25.11 b). According to the angulation of the optics, the main operative field lies slightly in front of and below the tip of the optics. This area is exposed and maintained by a combination of gas insufflation and mechanical dilatation.

The *basic element* has an integrated handle which is firmly attached to the double-ball joint after the operative field has been exposed. Seals between all connecting pieces prevent gas leakage.

The rectoscope is introduced after a dilator with an atraumatic tip has been inserted. To facilitate endoscopic assessment, the dilator is then replaced by an adaptor with viewing window and an illumination insert.

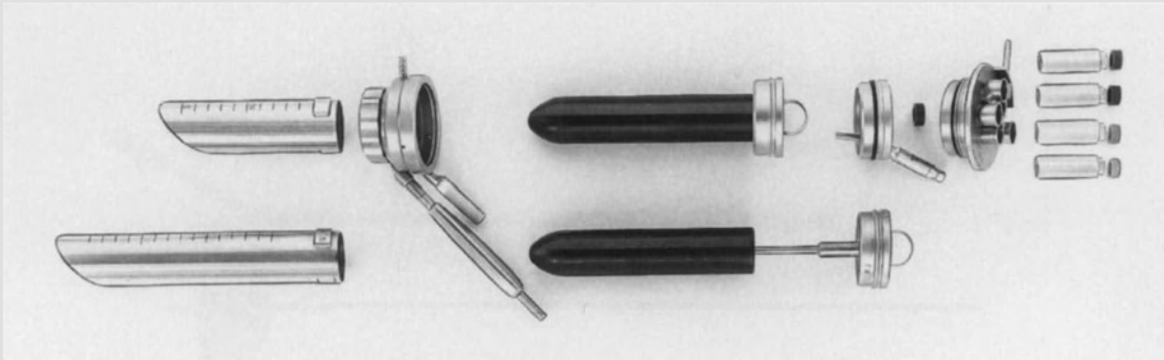
The insert for the endoscopic optics and instruments is mounted prior to the actual operation phase. The insert has four ports closed off by sealing sleeves with various sealing caps for the instruments and a locking device for the fifth, which is the optical port (see Fig. 25.11 a).

The Martin Retractor

Examination of the tissue under optical magnification requires that there be a stable working position, which can be ideally secured by the Martin arm. Its three joints can be fixed and released in a single manipulation by a central adjusting screw.

The Optics

The stereoscopic optics (see Fig. 25.9 b) provides a three-dimensional, enlarged image. The interocular distance of the optical eyepiece can be individually ad-



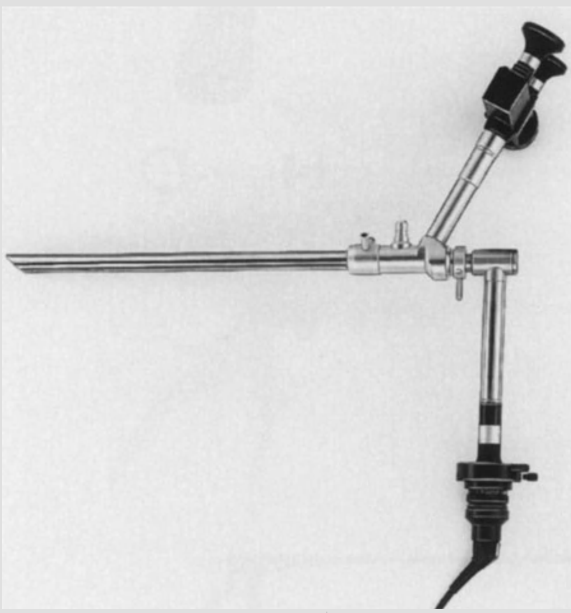


Fig. 25.9 a, b. Operating rectoscope and optics. **a** The parts of the operating rectoscope. **b** The stereoscopic optics with rigid attachment for simultaneous viewing

justed. An additional third optics serves as a semiflexible teaching attachment for direct viewing, alternatively, rigid optics for video monitoring can also be introduced.

Integrated into the optics are channels for rinsing the optic front lens and for CO_2 insufflation.

The Surgical Instruments

Several of the endoscopic instruments incorporate leads for monopolar high-frequency application. The grip and shaft of these instruments are insulated and a high-frequency cord is connected to the grip. The tips of the instruments are not insulated, thus permitting high-frequency current to flow freely to the tissue.

The high-frequency knife is slightly bent at its tip, bringing the tip of the instrument into the optimal viewing area. The pistol grip allows ergonomic handling of the instrument. There are two reasons that the tip of the endoscopic forceps, the needle holder, and the suction probe are tilted slightly downwards. First, the sacral concavity can be reached better, and secondly, the distance between optics and instrument is increased, improving the visual control of the manipulation (see Fig. 25.11 b). The jaws of the endoscopic forceps have sharp ridges for grasping and securing tissues running transverse to the long axis. The remaining surface of the jaws is slightly roughened to grasp needle or thread in an atraumatic manner.

The jaws of the needle holder are shaped so that the needle automatically aligns when grasped. The variceps handle of the needle holder permits the instrument to lock the needle in any rotation position.

For securing the thread we use a special sliver clip (Fig. 25.10; see also Fig. 25.17). This material is sufficiently malleable to ensure that the regularly used monofilament suture is not severed during compres-

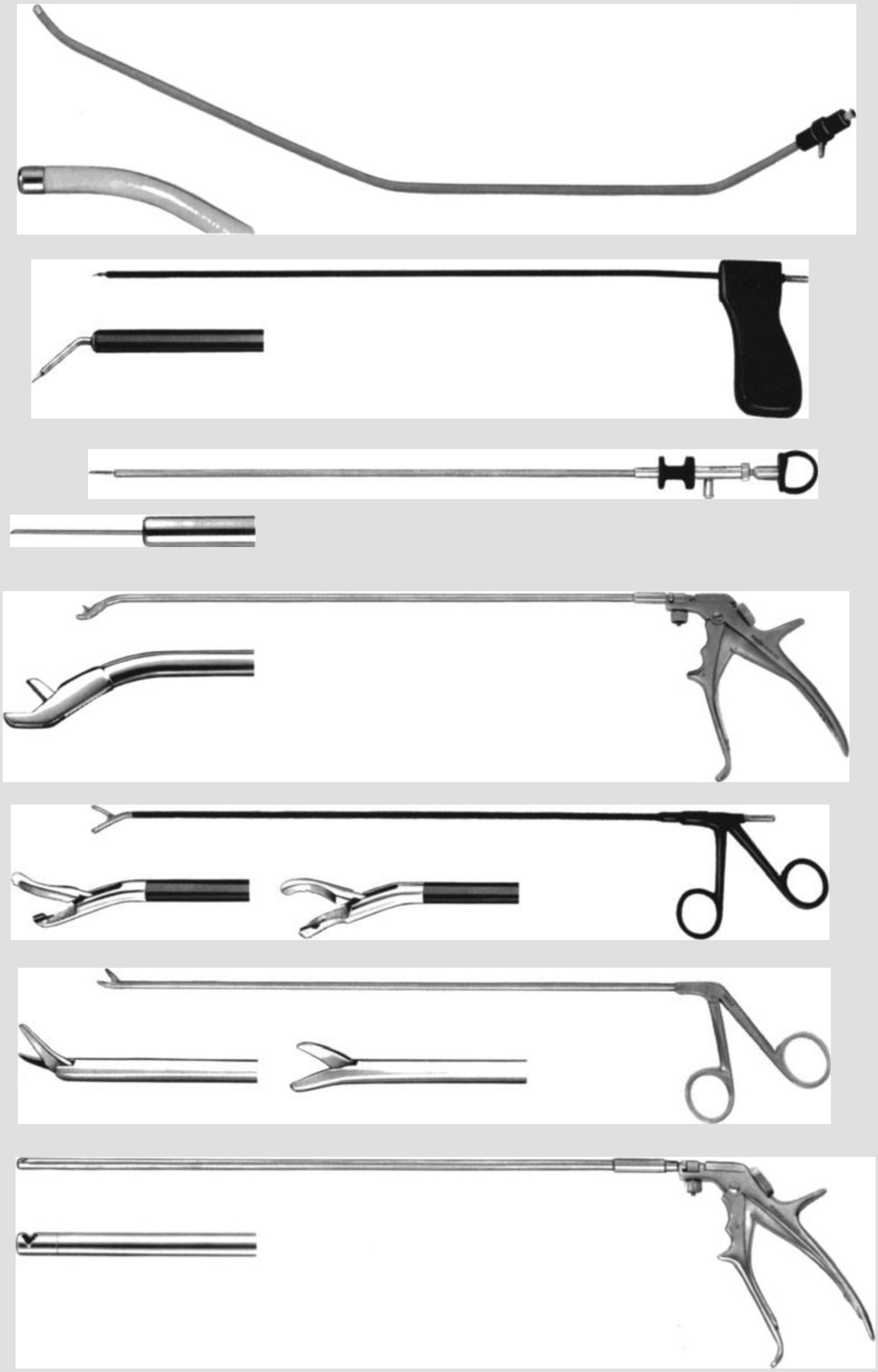
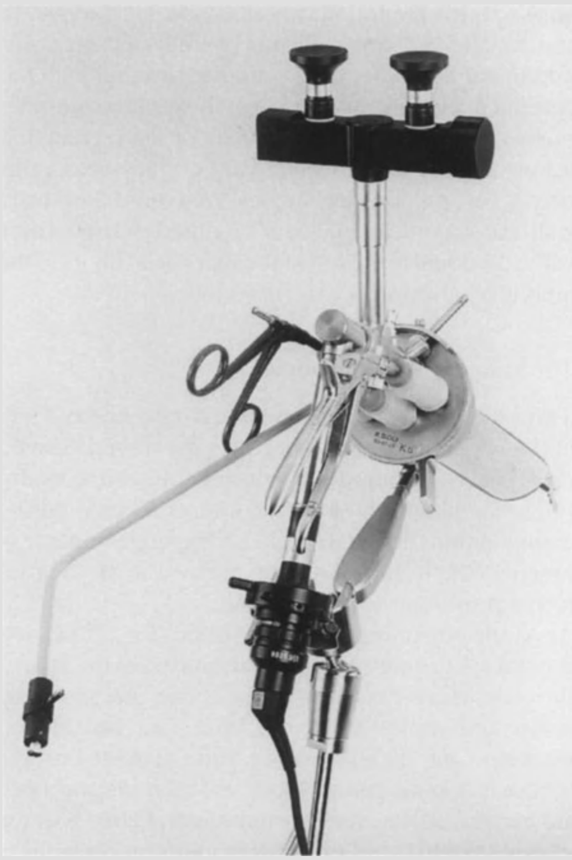


Fig. 25.10. The endoscopic instruments. *Right,* the hand grips; *left,* the instrument tips



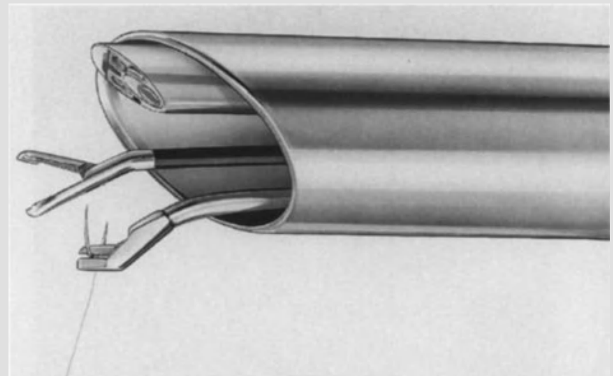


Fig. 25.11 a, b. The completely assembled operating rectoscope. **a** Optics and instrument ports; **b** the tip of the instrument

sion of the clip. After resorption of the suture material (polydioxanone), the sliver clips are passed with the faeces. The clip applier has a variceps handle as well (Fig. 25.10); the clip is introduced with its slit running transversely to the longitudinal axis of the instrument.

The aspiration/coagulation probe is angulated in several directions. This complex form allows the assistant to aspirate without hindering the technical progress of the operation by the surgeon or the advancement of other endoscopic instruments.

With the aid of a retractable needle alpha-adrenergic agents can be injected before or during the operation.

Operative Steps

Set-up of the Operative System

The operation is started by rectoscopy. If the upper margin of a tumor is located below an imaginary line approximately 12 cm from the anal verge, a short rectoscope tube is used. After a lubricated atraumatic dilator has been introduced, the sphincter is negotiated gently. Subsequently the adaptor with viewing window is attached to the basic element, the cold light cable connected, and the tumor area exposed by manual room air insufflation. Optimal exposure is secured by the U-shaped support arm.

The viewing adaptor is then exchanged for the working insert, which already contains the sealing sleeves and caps on the instrument ports. The operative system is connected by tubes to the endosurgical combination unit as marked. Each function of the system is checked immediately prior to surgery: suction, gas insufflation, and optic lens rinsing. To perform this system test, the gas bottle must be opened, and the electrical power and the insufflation switched on.

The stereoscopic optic piece is then inserted via the respective port, attached either to a semirigid teaching telescope or video camera, and arrested with the front lens still within the tube. The endoscopic instruments are subsequently introduced under visual control. For a right handed person, the left upper port is reserved for the forceps and sealed with a red cap, the right up-

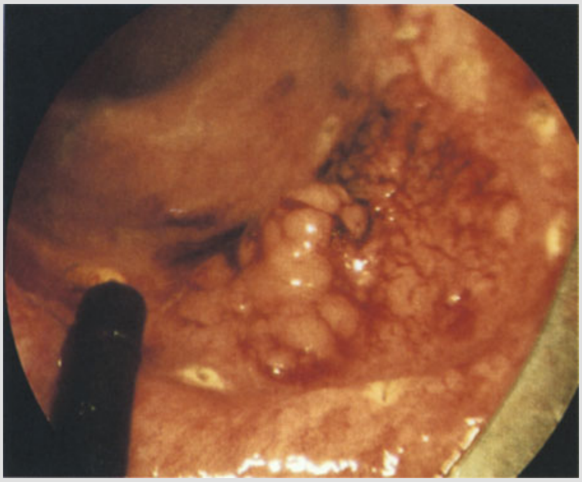


Fig. 25.12. Marking of the resection line by coagulation dots

per port holds the high-frequency knife and is sealed with a red cap, the left lower port accomodates the suction probe and is sealed with a grey cap, and finally the right lower port is usually sealed off with a red cap without opening. Now each connection has been made and a gas-tight environment established.

The insufflation unit is switched on and the optics advanced until the rectoscope rim just vanishes from the field of view. In this position the tip of the optics is still within the protective perimeter of the beveled wide-lumen rectoscope (Fig. 25.11 b).

Positioning of the Optics

We start the operation by assessing and securing the optimal working position. To do this, the Martin arm is released and the entire tumor area scanned for direct viewing. At this stage definite confirmation is reached as to whether each tumor site is accessible and whether the TEM procedure is feasible and safe.

Definition of Safety Margins and Excision Techniques in Rectal Tumours

In adenomas a safety margin of at least 5 mm and in carcinomas a safety margin of at least 10 mm is ideal. The imaginary resection line is marked by coagulation dots prior to excision (Fig. 25.12). This ensures excision with the required safety margins, especially when bleeding obscures the local anatomy. For all tumors located in the extraperitoneal part of the rectum we always employ the full thickness excision technique. In the case of a carcinoma located laterally or posteriorly, additional perirectal fat is removed together with the specimen. To prevent opening of the peritoneum, adenomas of the intraperitoneal part of the rectum and lower sigmoid are resected by the mucosectomy or partial wall excision techniques. We regard the partial wall excision technique as a modified mucosectomy with additional resection of the superficial fibers of the muscularis propria.

The Mucosectomy Technique

Two aspects are of special practical importance. First, at the beginning of the procedure the surgeon should exert great care not to excise too deeply, and secondly, the lesion should be handled with great care during manipulations in order to keep the edges intact. In practice, the lesion should be grasped in all excision techniques along normal mucosa.

At the beginning of the operation (Fig. 25.13), use the forceps to carefully grasp the mucosa in the area of the coagulation markings at the aboral margin of the polyp and gently lift it up. With fine coagulation strokes of the high-frequency knife activated by the foot switch in the cutting mode and with the appropriate current setting, the incision is carried down to the silvery shining fibers of the muscularis mucosae. This step of the procedure has to be performed with as much magnification as possible. An enlarged image is obtained by advancing the optics towards the area of interest. To further mobilize the tumor, the previously elevated mucosa together with the adenoma is flipped over proximally and further mobilization of the lesion performed from either side of the resection area. Major bleeding is rarely encountered during mucosectomy. Nonetheless, each bleeding requires instant counter-measures as otherwise the view of the resection area is rapidly lost. In case of an active haemorrhage, the assistant quickly advances the suction probe, aspirates the field, detects the bleeding vessel, and compresses area while coagulating with the suction probe (Fig. 25.13 c).

Because of frequent upward and downward folding of the proximal margin of the mucosal "flap," the resection margins have to be constantly visualized during the excision (Fig. 25.13 d). At the end of the operation absolute haemostasis must be established.

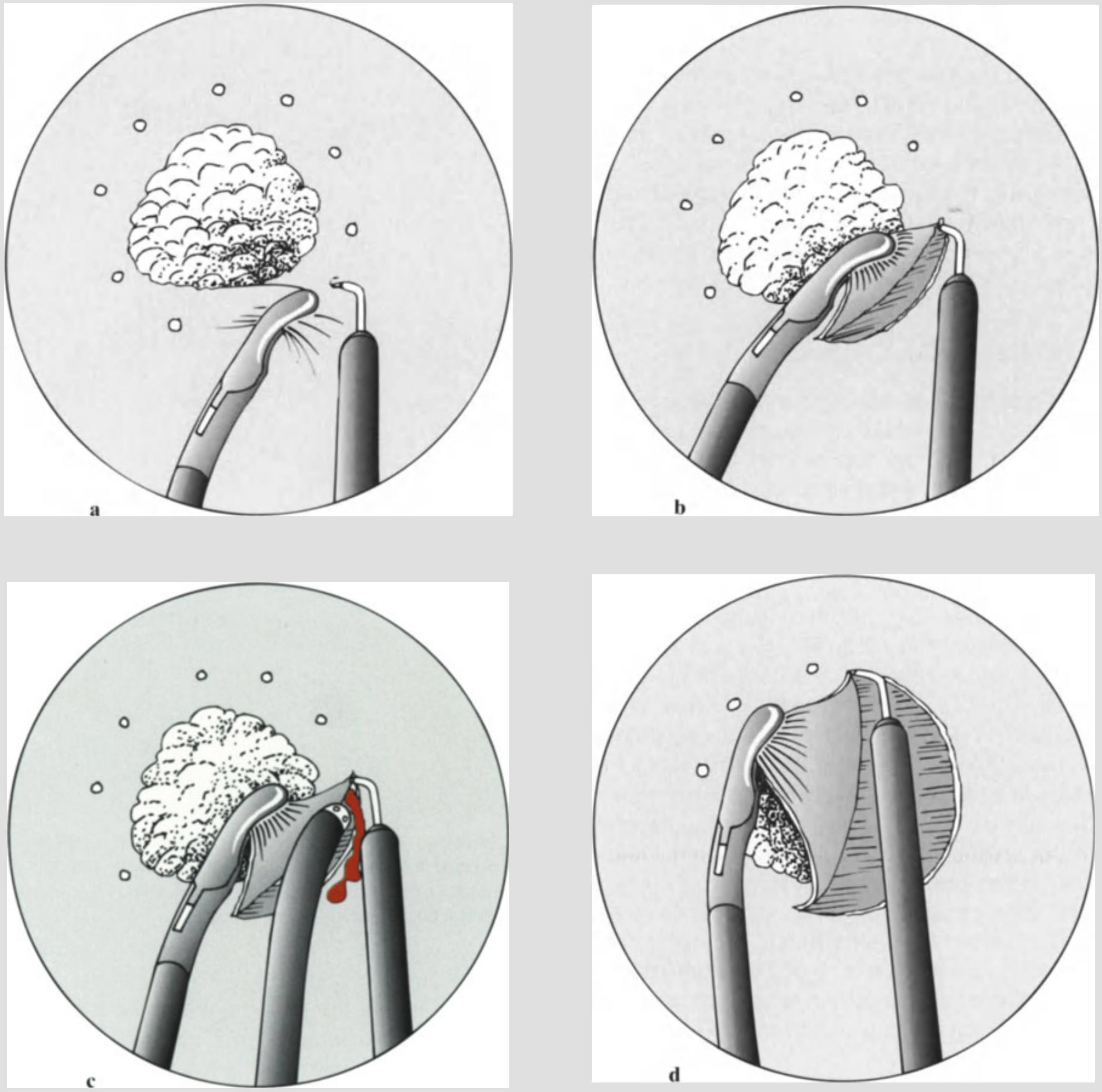


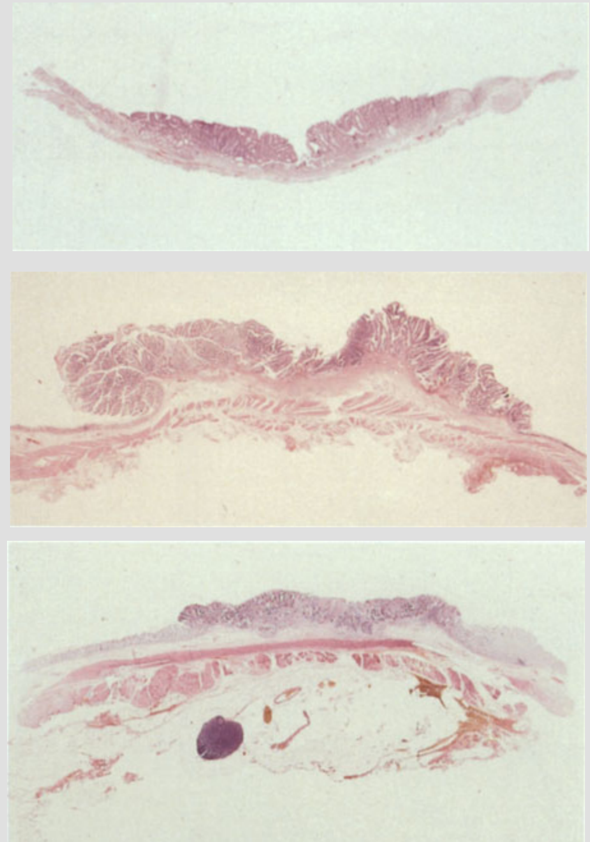
Fig. 25.13 a–d. The mucosectomy. **a** Lifting of the mucosa prior to excision. **b** Dissection of muscularis externa at the lower border of the polyp. **c** Compression and coagulation with the suction probe. **d** Excision at the upper border of the polyp

The Partial Wall Excision Technique

In principle, partial wall excision is conducted in the same manner as in mucosectomy. In the case of large polyps located in the intraperitoneal part of the rectum, the lesion is kept intact by the partial wall excision, as distinct from mucosectomy, thereby increasing the probability of curative resection. Partial wall excision is also indicated for tumors close to the anal crypts.

Full Thickness Excision Technique

Two arguments favour the regular performance of full thickness excisions in the extraperitoneal part of the rectum. First, this approach ensures that an excision with the necessary depth is performed for pT1 carcinomas. Secondly, it allows the removal of a large lesion with intact margins and thereby adequate excision (Fig. 25.14).



a b c

Fig. 25.14 a–c. Operation specimen. **a** Polyp resected by the mucosectomy technique. **b** Polyp resected by the full thickness technique. **c** Polyp resected by the full thickness technique with retrorectal fat and tumor-free lymph node

The operation starts at the coagulation dots along the lower resection line. The full thickness of the bowel wall is divided by the first coagulation strokes. Bleeding vessels encountered in the muscular wall are immediately electrocoagulated. After aspiration and detection of bleeding points, vessels up to about 1 mm in diameter are directly electrocoagulated with the suction probe. Larger vessels are first compressed with the suction probe, the high-frequency knife replaced by the insulated endoscopic forceps, and the vessel then grasped, compressed, and coagulated (Fig. 25.15 a). After mobilization of the distal border of the polyp, the incision is carried on along its lateral aspects. The positions of the rectoscope and optics have to be changed frequently in order to maintain an optimal working position.

When the incision around the tumour has reached its proximal border, the rectoscope is again changed to expose the lower tumour border and excision of the tumour base is started. In the case of an adenoma, this extends to the layer between the outer longitudinal muscle fibers and the perirectal fat.

Again, the mobilized bowel wall surrounding the tumour is lifted upwards and, in case of large tumours, folded upwards (Fig. 25.15 b). During this step of the procedure, spurting arterial haemorhages are often encountered and require control either by suction probe or forceps. Vessels identified during the excision are first coagulated before being divided (Fig. 25.15 c). The bowel wall division is completed when the upper tumor margin is reached. Orientation is established as in mucosectomy by alternate displacement of the upper and lower margins of the tissue flap surrounding the tumour. When the tumour has been entirely excised the working insert is removed and the specimen extracted. After the working insert has been replaced, the operative field is carefully inspected and any residual bleeding controlled. Finally, the resected specimen is spread out and pinned onto a cross-hatched cork plate (Fig. 25.16).

En Block Resection of Perirectal Fat (Fig. 25.14 c)

During en bloc resection of perirectal fat required for carcinoma located posterolaterally in the extraperitoneal part of the rectum, large blood vessels may be inadvertently cut. Bleeding from these vessels is controlled by electrocoagulation using the suction probe. However, the vessels may retract in the perirectal fat and renders hemostasis difficult. A better technique consists of selective grasping of these vessels with the insulated endoscopic forceps, followed by electrocoagulation.

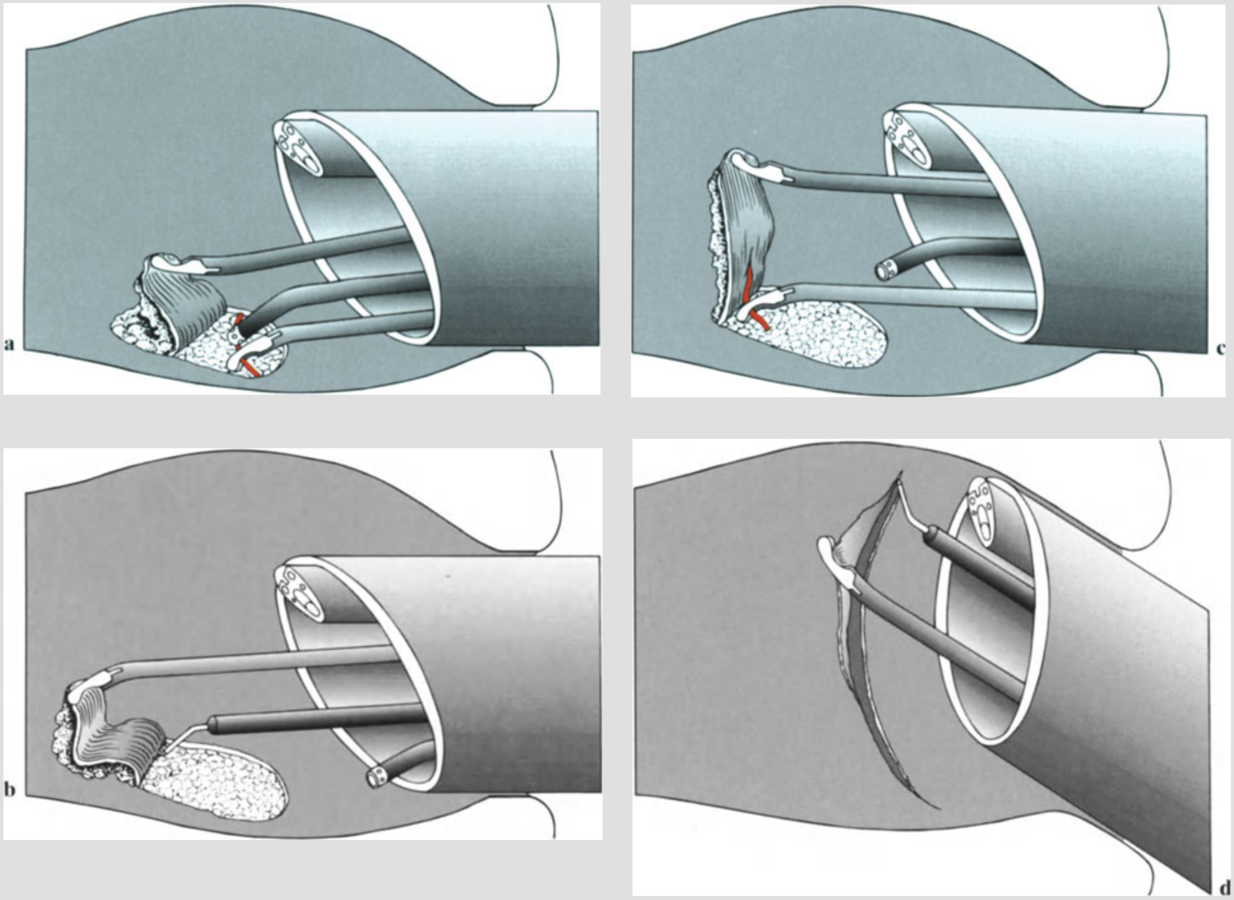


Fig. 25.15 a–d. Operation steps of the full thickness excision technique. **a** A larger vessel is compressed by the suction probe, grasped with the forceps and coagulated. **b** For excision at the tumour base the tumour-bearing area is turned over. **c** Structures containing blood vessels are grasped and coagulated prior to division. **d** Preparation at the anterior rectal wall in the maximally tilted working position

Inadvertent Opening of the Peritoneal Cavity

In every resection within the intraperitoneal part of the rectum inadvertent opening of the peritoneal cavity may occur as a result of the line of excision being carried out too deeply. This complication results in escape of CO_2 into the peritoneal cavity, with a consequent fall in the intrarectal gas pressure such that the endoscopic view is severely compromised.

Therefore the defect has to be closed immediately. To ensure placement of the silver clips intraluminally, the first stitch has to start from the luminal side and finally has to be returned back into the rectal lumen (see

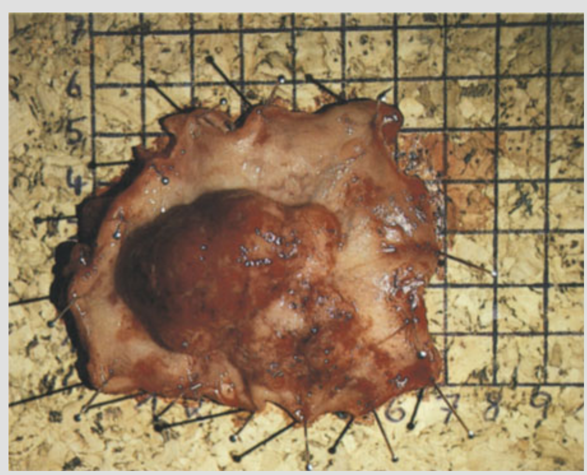


Fig. 25.16. Operative specimen pinned to a cork plate

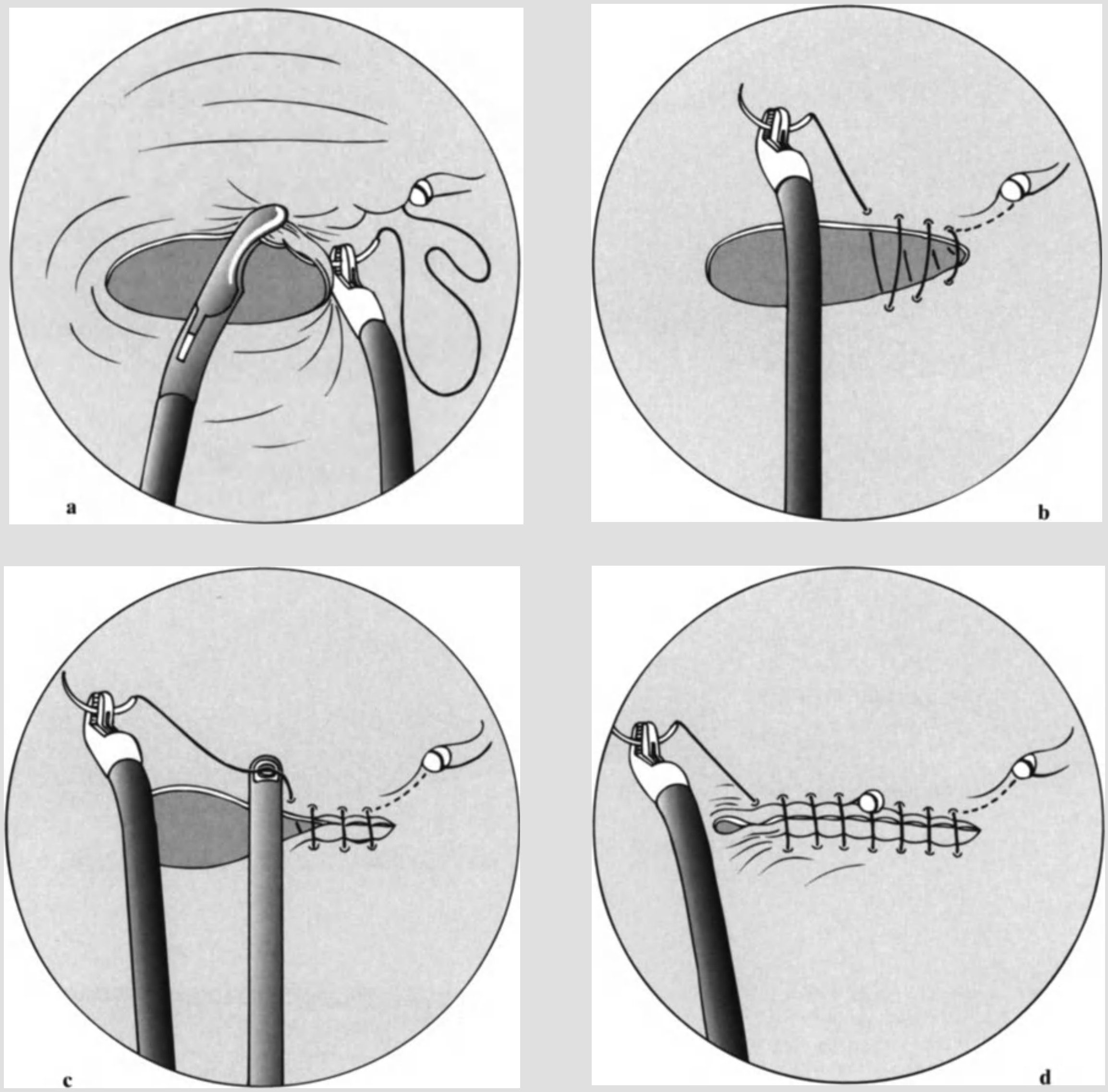


Fig. 25.17 a–f. Defect suturing in TEM. **a** 8 cm long monofilament thread with silver clip at its end. **b** Suturing by continuous, transverse technique starting at the right wound edge. **c** To reduce stress on the suture, the achieved defect closure is secured by application of intervening silver clips. **d** Suture close to the left wound edge

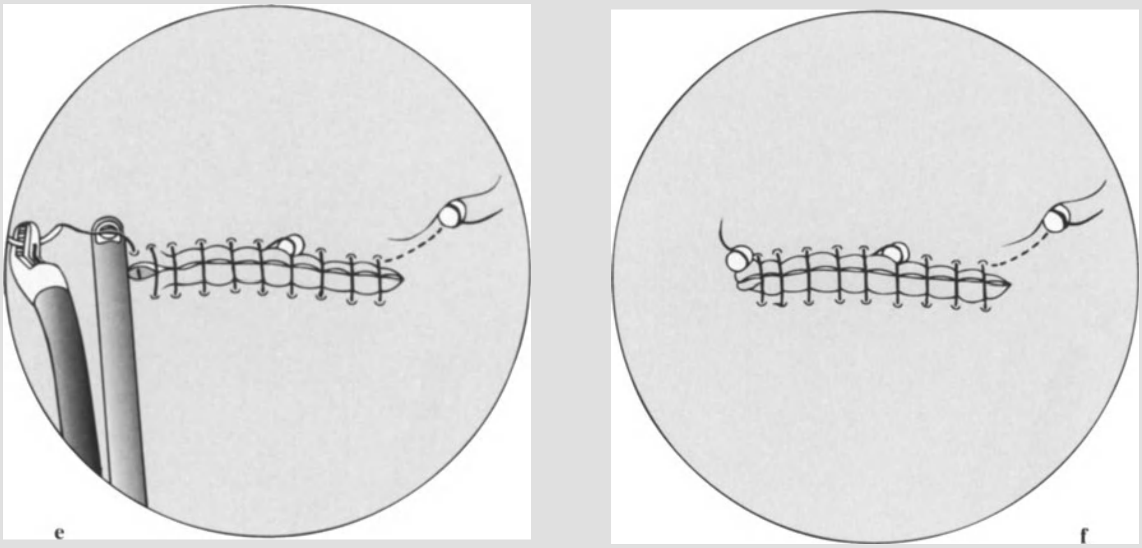


Fig. 25.17. e In order to achieve complete closure the fold at the left wound edge has to be especially taken care of. **f** Complete suture clip application

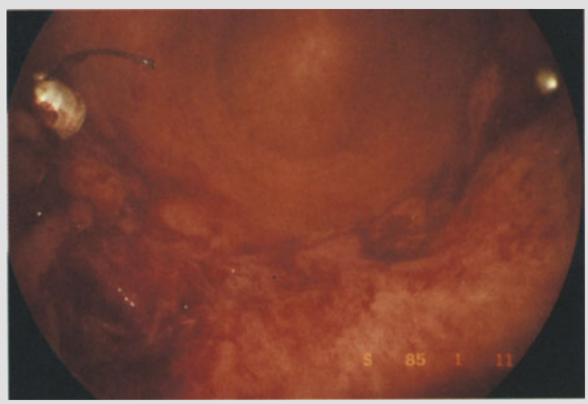


Fig. 25.18. Endoscopic picture of the completed suture

Fig. 25.19 b). The risk of opening the peritoneal cavity with inadvertent laparoscopy and pneumoperitoneum is reduced by ensuring that excision within the intraperitoneal part of the rectum is carried out as carefully as possible.

Segmental Resection

A segmental full thickness resection is only possible in the middle third of the rectum. In more proximately located tumours, at least the ventral aspect of the resection has to be carried out as a mucosectomy or partial wall excision. A prerequisite for segmental resections is the feasibility of extreme upward tilting of the rectoscope (Fig. 25.15 d) in order to be able to operate and suture at the anterior wall. A segmental resection should be performed only by a very experienced endoscopic surgeon.

The Suturing Technique

The Uncomplicated Suture

As suture we use a 3/0 PDS thread with an SH needle. A silver clip is pressed onto the thread at about 8 cm and the remainder cut approximately 5 mm behind the clip. The empty needle holder is first mounted with a silicon sealing sleeve and then the needle inserted with its tip pointing towards the surgeon. To prevent a rectal stenosis in the area of defect closure, the suture is conducted in a transverse manner. The first stitch is always directed from the luminal side to the retrorectal aspect at the right edge of the defect (Fig. 25.17). The suture is then carried on in a continuous transverse fashion (Fig. 25.18). To reduce tension on the thread and to maintain the already established approximation, additional silver clips are applied intermittently. To close a semicircular defect up to four 8-cm threads are used.

As the suturing reaches the left edge of the wound an overhanging fold regularly forms, giving the im-

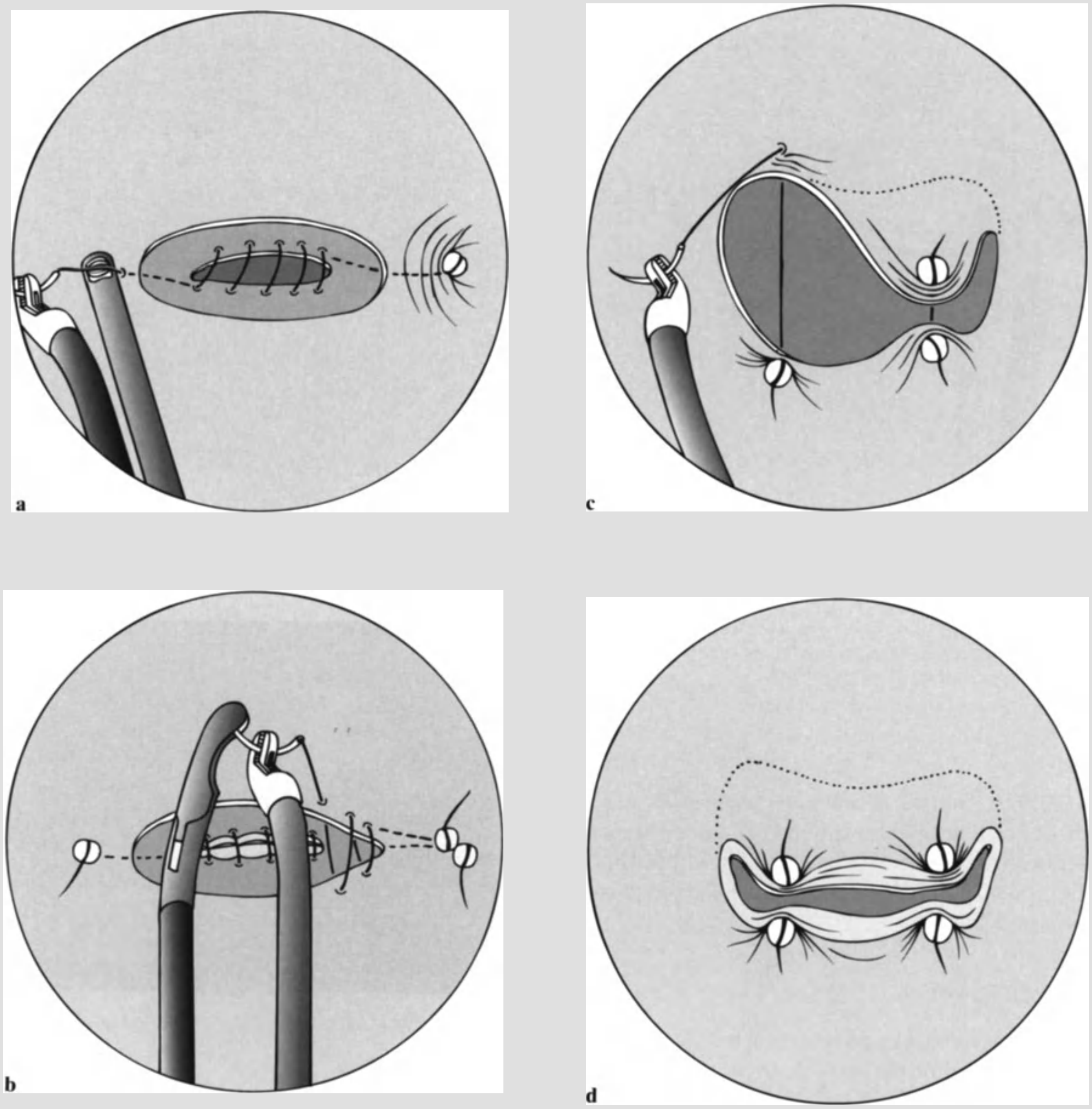


Fig. 25.19 a–d. Special situations in suturing. **a** Starting the suture in closing a peritoneal defect. **b** Termination of suture in closing a peritoneal defect. **c** Application of stay sutures in extensive longitudinal defects. **d** Stay sutures prior to final defect closure

pression that wound closure is complete. This fold has to be lifted to ensure that suturing reaches the left margin and a complete closure is achieved.

Suturing Extensive Defects

After resection of extensive longitudinal growth and following segmental resections, the suturing is facilitated by the application of temporary stay sutures. The wound edges are first approximated by several interrupted stitches to a distance of about 5 mm (Fig. 25.19 c, d). Afterwards standard transverse suturing is performed.

Procedure in Transanal Endoscopic Rectopexy

When performing transanal endoscopic rectopexy with TEM instruments, the posterior wall of the middle rectal third is divided, the presacral ligaments are exposed, and the posterior upper third of the rectum attached to these structures with U-shaped sutures. The surgical technique is equivalent to that discussed for carcinoma. With the long rectoscope, the middle rectal third is exposed and the sacral promontory as well as the sacral curvature palpated with the suction probe (Fig. 25.20 a). The posterior rectal wall is divided completely in the middle of the ascending sacral curvature and the perirectal fat transected. The presacral ligaments are exposed for a length of about 5 cm (Fig. 25.20 b). The first rectopexy stitch secured with a silver clip is then carried out from the luminal side, runs through the presacral structures, and is returned back into the rectal lumen (Fig. 25.20 c). After two or three of these sutures are placed, the rectal incision is again closed by transverse continuous suturing (Fig. 25.20 d). The U-type sutures are put under tension at the end of the procedure using another silver clip.

Postoperative Care

General Rules

The postoperative course in TEM is comparable to that of other transanal procedures. After TEM moderate to severe pain necessitating administration of oral analgesics is encountered only after resections close to the sphincteric region. The patients may get out of bed on the day of operation and should lie down only for short periods on the first postoperative day.

Especially in the first 24 h, micturition has to be watched carefully. During TEM the urethra is mechanically traumatized to a varying degree by being forced against the symphysis when manipulating the operation rectoscope. If micturition difficulties are encountered, catheterization or in few patients insertion of a Foley catheter is indicated. Micturition difficulties persist for several days only in a small percentage of patients.

After full thickness excision transient pyrexia of up to 38.5 °C is frequent but this usually returns to normal by the second to fourth postoperative day. Most probably, this rise in temperature is caused by degradation and subsequent resorption of coagulation products and inflammatory mediators from the perirectal tissues. As long as the temperature remains below 38.5 °C with no signs of septicemia, we adopt a simple observation policy.

In the majority of patients minimal blood loss per rectum (<5 ml) is seen in the first few postoperative days. Bleeding can either be from the suture line or from a mucosal tear anywhere in the anal canal.

Diet and Length of Hospital Stay

After mucosectomy, on the first postoperative day the patient is given clear liquids, and on the second day regular meals; from the third day on discharge is possible. After full thickness excision, on the first and second postoperative day the patient is given i.v. fluids and oral clear liquids, and on the third day full liquids to house diet; from the fourth postoperative day on discharge is possible.

Management of Complications

When the postoperative temperature rises above 38.5 °C or the pyrexia remains elevated for more than 4 days or when bleeding per rectum exceeds 10 ml, wound dehiscence must be strongly suspected. A rec-

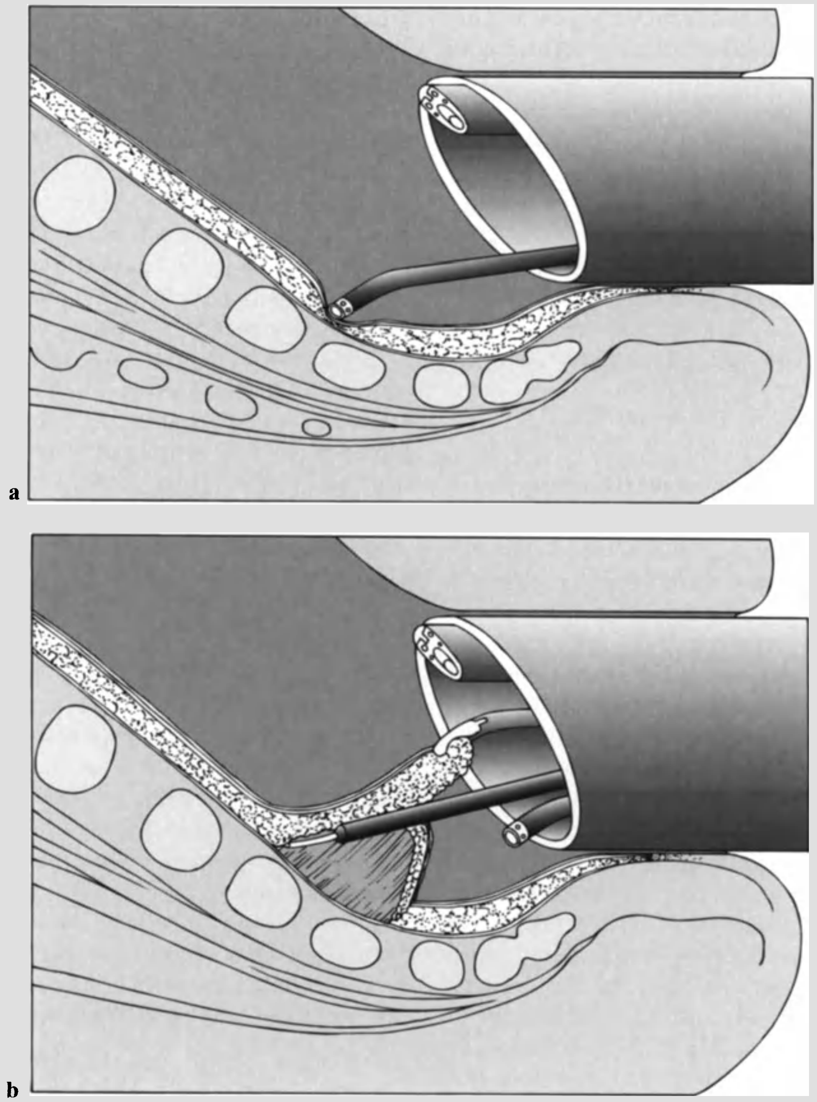


Fig. 25.20. **a** Palpation of osseous structures. **b** Exposure of Waldeyer's fascia up to a length of 5 cm

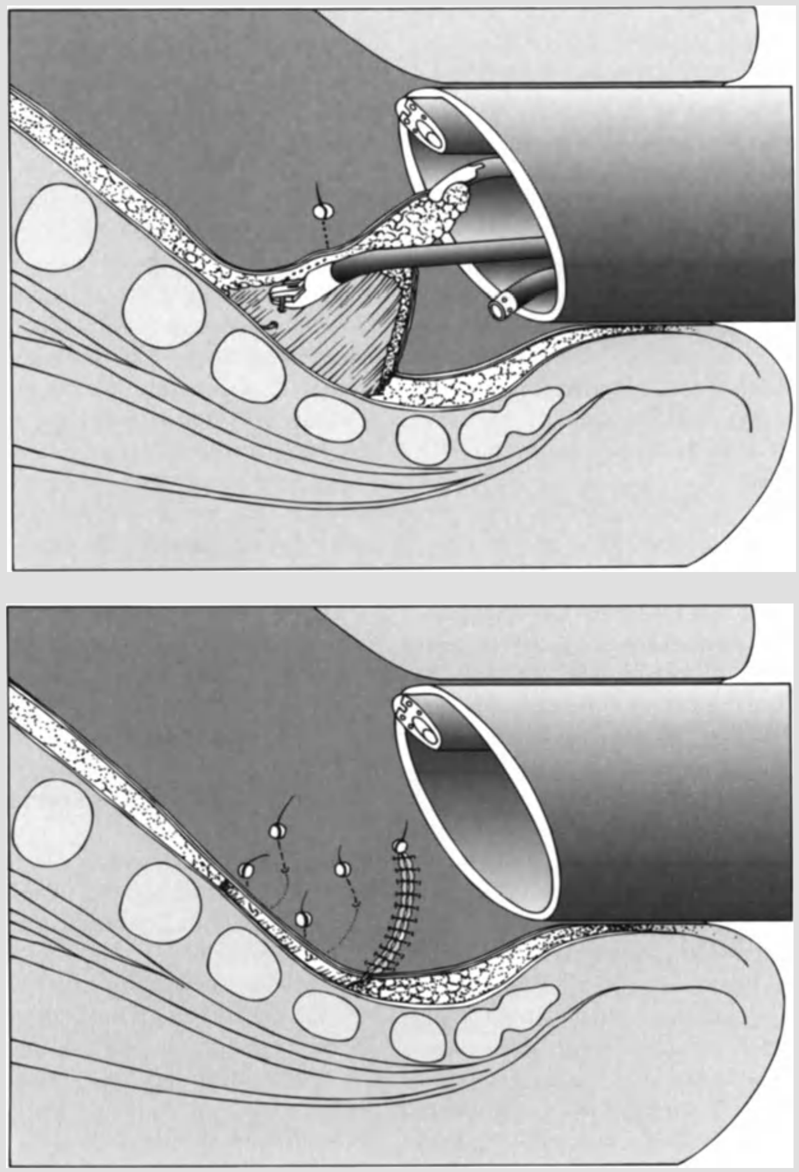
toscopy is then performed to evaluate the extent of the defect and the local response. When endoscopy cannot safely rule out dehiscence of the suture line, a water soluble contrast enema is performed.

If dehiscence of the suture line is documented, parenteral nutrition and antibiotic therapy are started. Usually the temperature drops within the next few days and oral diet is recommended. A colostomy is necessary if the patient develops sepsis and a large dehiscence.

When more severe rectal bleeding is encountered an emergency rectoscopy is required. The blood is evacuated by means of an insulated suction probe, and the bleeding source identified and coagulated with monopolar high-frequency current.

Follow-up Examinations

After resections for adenomas follow-up examinations are conducted annually, with alternating retoscopy with colonoscopy. After full thickness exci-



c

d

Fig. 25.20. **c** Fixation of posterior rectal wall to the pre sacral fascia with U sutures. **d** Completed rectopexy

sions and in patients who develop postoperative complications, the first follow-up visit is scheduled for the fourth postoperative month. After operations for carcinoma, patients return for follow-up visits every 3 months in the first postoperative year and 6 monthly thereafter.

Results

Patients

At the University Hospitals in Cologne, Mainz, and Tübingen, we performed a total of 314 operations with TEM in the period from July 1983 to September 1990. A total of 227 adenomas, 74 carcinomas, four carcinoids, three hyperplastic polyps, one malignant lymphoma, and one rectal ulcer were excised, and in four patients a rectopexy performed.

The data presented refers to a prospective study conducted at the University of Mainz from 1986 to 1989.

The average age of the patients with adenomas was 63.7 years, and for carcinomas 68.5 years. The distribution of the site of the tumours extended up to 24 cm from the anocutaneous line. In 40% of the operated adenomas snare resection and in 10% surgical removal had previously been performed. Two-thirds of the patients with adenoma were symptomatic with frequent bloody and mucoid discharge.

Adenomas as well as carcinomas were mostly resected with the full thickness technique (adenomas in 63%). In 13 of 49 carcinomas the retrorectal fat was removed together with the specimen. The average operation time was 84 min. The usual operating time for an adenoma of 3 cm diameter is less than 1 h, for a segmental resection less than 2 h.

Complications

The postoperative complication rate in 136 operations for adenomas was 5%. In one case a sigmoid resection was performed due to the location of the tumor in the intraperitoneal part of the rectum. The mortality rate of TEM to date is 0.3%; this female patient succumbed from a pulmonary embolism. In five patients local wound healing complications led to stenosis of the suture line which responded to bouginage. In carcinoma patients severe wound-healing impairment was encountered in two patients, necessitating temporary protective colostomy.

Micturition difficulties are seen frequently in the postoperative course but usually disappear after 24 h. They are thought to be caused by a mechanical trauma of the urethra during manipulations with the operating rectoscope. In most cases a single catheterization is usually sufficient. Micturition difficulties of a longer duration can be caused by local impaired healing of the suture line.

Partial incontinence is frequent during the first few postoperative days. However, after 1 week continence is usually back to normal. In one out of 186 patients incontinence persisted after 5 months postoperatively whereas in the remaining patients sphincter function returned to normal.

Histologic Findings

The mean surface area of the resected specimen was 17.7 cm^2 in adenomas with a mean tumour area of 11.7 cm^2; in some cases surface area exceeded 100 cm^2. In carcinoma this difference was greater due to the larger resection margins.

In adenomas G1 stage was found in 17, G2 stage in 96, and G3 stage in 24 cases. In four adenomas which were not completely resected on macroscopic assessment, histologic workup showed tumor at the resection margins. In an other six cases with macroscopically complete resection, the resection margins contained tumor on histological examination.

The diagnosis of a carcinoma was known preoperatively in only 16 of the 49-resected carcinomas. In all other cases carcinomas were accidentally found, most commonly in large sessile adenomas. In 40 out of 49 cases the tumor was confined to the submucosal layer, in 37 out of these 40 cases grading was G1 or G2 (pT1 low risk), and in three cases grading was G3 (pT1 high risk). Seven cases were pT2 and 2 pT3.

In four patients histologic workup could not definitely rule out incomplete resection. In three of these patients no malignant cells were detected in the rectum which was subsequently resected.

The histologic examination of five specimens containing carcinoma showed a total of nine tumor-free lymph nodes in the retrorectal fat (Fig. 25.14c histology).

Results of Follow-up After Local Excision

A strict routine follow-up regimen was conducted in all locally operated patients. A follow-up rate of 81% was achieved with an average follow-up period of up to now 14 months.

In follow-up of patients with a previous adenoma we make a distinction between recurrences in close proximity to the resection area and new adenomas situated away from the resection area. Sometimes this distinction is hard to make as small "buds" of new adenomas frequently appear close to large sessile adenomas.

Up to now in adenomas we have detected seven recurrences and ten new polyps. In only three cases was a second operative intervention necessary; in the remaining seven cases small polyps could be removed either by hot biopsy or snare resection.

Some of the patients with locally resected carcinomas were reoperated radically. In those patients who were only resected locally, the following follow-up results have been observed. Out of 25 controlled patients with low-risk carcinoma, only one patient developed an extensive local recurrence and liver metastases. A review of the histology of the original specimen showed that resection had not been complete. In two out of three locally resected high-risk carcinomas, local recurrences were detected which were treated by radical reoperation. In six locally resected pT2 carcinomas, one local recurrence was found which was treated by radical reoperation with curative intention.

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Part IV Way Ahead

26 Quality of Life and Assessment of Endpoints

M. B. Naruhn and G. Buess

Introduction

Since its introduction as a separate heading in *Index Medicus* in the year 1977, "Quality of Life" (QL) has aroused increasing interest among medical professionals. In surgery, numerous efforts have been made in recent years to establish QL as a relevant endpoint (outcome) variable in clinical studies. With the advent of endoscopic surgery (ES) and its decisive positive influence on postoperative pain, mobility and functional status, the measurement of the overall QL is receiving close attention as an index of clinical outcome.

The nature of QL is subjective, that is, it reflects personal viewpoints. Thus the term QL has different meanings to different people at different times and in different places, preventing a universally valid definition. Nevertheless, there is general agreement in the medical community that most of the important features (dimensions) of a QL construct are already contained in and characterized by the definition of health by the World Health Organization: "Health is a state of complete physical, mental and social well-being ..."

Endoscopic Surgery and Quality of Life

There was for many years no alternative to "open" surgery. Today with increasing surgical endoscopic practice and the constant introduction of new methods of ES, QL research has assumed even greater importance in the assessment of the relative cost-benefit ratio and efficacy of conventional open surgery and the new endoscopic surgical procedures. This assessment is based on the use of target variables (study endpoints, outcome parameters) such as discomfort, pain, mobility and functional status. It is especially owing to this young field of surgical research and clinical application that interest in postoperative QL as a relevant outcome parameter has grown in the last decade.

The primary goals of ES are to minimize the trauma necessary to expose the pathology (incisional and retraction trauma) and the trauma during the actual surgical work at the operation site (target tissue trauma). This is achieved by the reduction in size of the endoscopic instruments; the use of trocars as access ports, guiding tubes and retractor devices; the magnified image transmitted via the optical system; and the use of state of the art technology.

Reduced tissue trauma ought to result in less physical and emotional discomfort, pain, functional impairment and postoperative morbidity (e.g. pneumonia, pulmonary embolism) of the kind that tends to result from prolonged immobilization and a protracted recovery period. These advantages are, however, theoretical and need to be confirmed by prospective audit of surgical outcome using endpoint variables relevant to ES. A number of such studies are in progress or being set up. As an example, the design and data of a study on postoperative pain and mobility after laparoscopic cholecystectomy are presented later in this chapter.

The Value of Measuring Quality of Life

The merit of a more holistic, scientific approach to measuring QL during clinical trials in surgery is widely recognized, as in many instances surgical treatment intrudes into the patient's physical, emotional and/or social life. There is general agreement that for adequate measurement of the outcome of our surgical interventions and guidance of treatment the patients' subjective assessment of their health status – which in the majority of cases was the reason for the original surgical consultation – is as important as the collection of so-called hard data. In many instances easily measurable, quantifiable and reliable hard data such as hospital morbidity, mortality and survival rates do not adequately reflect therapeutic outcome. Therefore, in addition to conventional surgical outcome variables, the patients postinterventional subjective perceptions of, for example, discomfort, pain and functional impairment have to be carefully recorded and interpreted in order to reflect the patient's true health status.

Data on postoperative QL will have an increasing impact on the choice between alternative treatment modalities and on the identification of negative effects of disease and/or treatment. In equally curative surgical procedures, for instance open and laparoscopic cholecystectomy, significant differences in postoperative QL, provided morbidity and mortality rates are comparable, will increasingly influence the patient in favour of the endoscopic approach. The same process will, also alter other therapeutic strategies. Especially in palliative procedures, e. g. pain control in chronic pancreatitis or restoration of swallowing function in esophageal carcinoma, effective symptom control and influence on QL in general might become more relevant outcome variables than, for example, serum glucose levels or 5-year survival rates.

Some remarkable clinical studies have shown that the individual's perception of his or her health status may differ considerably from the surgical assessment, pointing to an increased need for adequate implementation of "soft data" surveys in clinical surgical research.

One study, carried out at the National Cancer Institute in 1981, tried to evaluate the impact on patient's QL of treatment for limb sarcomas. The patients received either amputations plus chemotherapy or limb-sparing surgery and radiotherapy plus chemotherapy. The evaluation of the eight well-established questionnaires that were used surprisingly showed little difference between the groups, with some measurement methods even showing greater QL in the amputation group. This result was not expected by the respective surgeons and strongly supported the incorporation of QL analysis into the evaluation of different treatment modalities.

With different procedures competing for the same health care resources, health care providers increasingly face the challenge of deciding which treatment modalities should be increased, maintained at present levels, or decreased. Quality of life studies have helped in the estimation of the relative cost effectiveness of various procedures by the formation of a "quality-adjusted life year" measure combining life expectancy and quality of life into a single unit of treatment benefit.

Quality-Adjusted Life Years

Quality-adjusted life years (QALYs) are a measure of the patient's improvement and satisfaction as a result of a given treatment and were first used to assess the cost-benefit ratio and economics of coronary artery bypass grafting. The unit is based on degrees of distress and disability first proposed by Kind et al. in 1982 (Tables 26.1, 26.2) from which a matrix is constructed. This enables the derivation of a fraction which is then multiplied by the expected survival after the intervention. Thus a patient with a matrix-derived fraction of 0.5 (based on distress/disability ratings) and an expected survival of 5 years would have gained $0.5\times5=2.5$ QALYs as a result of treatment. By contrast if the derived fraction is 0.9 and the expected survival the same, the benefit is greater, 4.5 QALYs. If the cost of the treatment is known, it can be expressed as amount per QALY and in this way forms a useful measure of the cost-benefit ratio of various treatments. Thus in Britain hospital haemodialysis costs £ 15000 per QALY as opposed to £ 3000 for renal transplantation, indicating the greater cost efficacy of the latter.

In the face of limited resources, future cost studies on surgical efficacy will be substantially aided by implementing the new concept of QALYs. Measuring the impact of MIS not only on the quality of life but also on health care costs and productivity in general will soon lead to re-evaluation of existing recommendations on treatment funding and distribution of treatment availability.

Table 26.1. Degrees of distress

A	None
B	Mild
C	Moderate
D	Severe

Table 26.2. Degrees of disability

I	No disability
II	Slight social disability
III	Severe social disability or slight impairment of performance at work or both; able to do all housework except heavy tasks
IV	Choice of work or performance at work severely limited; housewives and old people able to do only light housework but able to go out shopping
V	Unable to undertake any paid employment; unable to continue any education; old people confined to home except for escorted outings and short walks and unable to shop; housewives able to perform only a few simple tasks
VI	Confined to chair or wheelchair or able to move only with support
VII	Confined to bed
VIII	Unconscious

Measuring Quality of Life

Several QL instruments have been developed with an all-embracing scope of inquiry for the general population. Only minor but nevertheless clinically important changes are unlikely to be detected with such global measures, while disease-specific parameters are needed for patients with malignant diseases and, for instance, heart, joint, inflammatory bowel, chronic lung and kidney diseases. By their intrinsic design these disease-specific parameters usually have only a narrow range of applicability. For this reason, new QL parameters are required to evaluate the effect of specific treatment modalities on the quality of life of these patients.

This section is intended to outline for inexperienced investigators facing the problem of developing their own method of measuring QL the required strategy and a pragmatic approach to an individualized assessment for measuring within-subject change over a period of time. Basically two aspects have to be addressed: parameter design and parameter evaluation. Emphasis is be placed on the surgeon's input to the design of an individualized parameter. The terminology needed to understand the necessary basis of biostatistics are only highlighted; biostatistical advice is strongly recommended.

Parameter Design

Scope of Measurement

The first step in designing a tool for QL measurement is to decide whether the parameter should be a global, an overall measure assigning scores to overall QL, or whether a single dimension (area, component, domain, variable) of QL should be focused upon by a local measure. As an example, the often used Spitzer Quality of Life Index is a global measure, while its five areas – health, activity, daily living, support and outlook – are local measures. A global measure reflects the cumulative effect of its many local variables.

When limiting the analysis to certain dimensions, the full measure of the impact of the disease and/or treatment on the patient's life cannot be assessed. On the other hand, a study intended to be comprehensive may fail to reflect domains that are important to the patient and is likely to miss small but significant changes in the patient's postoperative course. As comprehensive studies are usually time-consuming with only limited compliance, in the surgical clinical setting selected relevant study endpoints are generally favoured over comprehensive enquiries.

Treatment and Patient Variables, the Definition of Relevant Study Endpoints and Item Selection

Clinical research is the identification and differentiation of bio-physico-chemical reactions of living matter to the controlled interventions of the investigator and the formulation of a working theory on how these controlled and uncontrolled variables interact.

Treatment variables are characteristics of medical interventions in general. The specific modality of care, the type of delivery to the patient, the equipment utilized, the use of adjuvant regimens etc. are said to be *independent variables* as they are manipulated by the investigator, constant in nature and objectively assessable and alter either by their therapeutic or placebo effect certain target variables of the respective patients. These *patient variables* affected by the respective treatment variables are called *dependent, outcome* or *endpoint* variables. They basically can be divided into two groups: The first group of outcome variables, the so-called *hard data,* can be objectively assessed by the investigator. They include laboratory data, data gained by imaging procedures, data on tissues, body fluids and excretions and physical performance, and morbidity, mortality and survival data. These variables may be recorded as positive (present) or negative (absent), as an absolute numerical value or as the degree of deviation from previously defined values or criteria. The second group of outcome parameters consists of variables which can only be gained by self-reporting (feedback) on the part of the patient. These so-called *soft data* differ within and between patients and may change with time, occasion and place. In many instances they cannot be regarded as separate from hard data and are vital to the interpretation and grading of hard data. For example, the walking distance of a patient with suspected occlusive peripheral vascular disease is dependent not only on the grade of vascular stenosis, pressure gradient and extent of collateral circulation but also on the patient's perception and tolerance of pain.

A pragmatic approach to describing and selecting relevant QL endpoints was presented by White as early as 1967. His classification of the five Ds – death, disease, discomfort, disability and dissatisfaction – has found widespread popularity because of its conciseness, comprehensiveness and mnemonic format:

Death (mortality rate) remains a major outcome variable in surgery. Nevertheless, for many procedures, e.g. cholecystectomy, herniorrhaphy or polypectomy, it is not very relevant.

Disease, as characterized by a combination of objectively assessable bio-physico-chemical parameters, signs and symptoms and only subjectively discernible and gradeable symptoms, is a major endpoint variable.

Physical and emotional *discomfort* can be caused by several factors, such as pain, anxiety, nausea, vomiting, poor appetite, fatigue and depression. Perhaps due to its seemingly subjective nature this endpoint has unfortunately been overlooked in a great number of clinical studies.

Postinterventional *disability* in performing activities of daily living, sport and routine occupational work has always been used as an important endpoint, as shown by the widespread use of the Karnofsky index.

Dissatisfaction with a given surgical outcome or a proposed therapeutic approach is increasingly altering the frequency of individual surgical procedures, as shown by the shift from open cholecystectomy to laparoscopic cholecystectomy.

Especially the latter three endpoints, discomfort, disability and dissatisfaction, will shift the emphasis away from disease – related parameters to patient benefit and will alter the way clinical outcome studies will be conducted in the future.

To choose among White's five Ds or in setting up additional endpoints, the guidelines according to Wood-Dauphinée and Troidl can be used. They stated that a study endpoint is relevant if it:

- Covers a true problem of the patient
- Responds with a high probability to changes in the therapeutic intervention
- Is a frequently occurring treatment effect
- Is a combination of physical, clinical and bio-physico-chemical data
- Is valid for future therapeutic regimens and covers as few variables as possible but as many as necessary
- Is precise and can be followed by other examiners

For the assessment of the impact of a given disease and/or treatment on self-assessment by the patient, a standardized questionnaire is generally thought to be superior to the clinical interview.

When the major endpoint variables are chosen, a comprehensive set of study items is usually collected by interviewing content-area specialists (physicians, nurses etc.) and a significant number of patients and family members as well as by reviewing the respective literature. This first preliminary, usually lengthy questionnaire is subsequently answered by a random sample of patients and covers of the whole spectrum of disease stages, intraoperative manoeuvres, postoperative complications, epidemiologic features etc. that theoretically may affect the outcome variables in question.

The aim of this item-selection questionnaire is to understand the frequency and importance of each item. This will enable the formulation of the final questionnaire which will omit those items which have been deemed unimportant in assessing the impact on the chosen endpoints.

Questionnaire Format

After a suitable questionnaire has been established, a method is needed to quantify the respective answers. The two best methods on grounds of simplicity, reliability and acceptance are (1) visual linear-analogue scales or 10-point Likert scales and (2) category rating scales.

In linear-analogue scales the patients marks his response to a given question on a single line with, for statistical purposes, a length of usually 10 cm. On each end of this line question-related extremes (highest, lowest) are marked, and the patient has to indicate where between these extremes his present state falls (Fig. 26.1). In the 10-point Likert variant, marks divide the line into ten equal parts to aid the patient's grading process. In category rating the patient is offered a series of statements or descriptions and asked to mark which single one ist most appropriate (Fig. 26.2). The advantage of linear-analogue scales is that they avoid the need to choose between categories that may be difficult for some patients to discern.

When these scales are applied each question will yield a point score and the individual scores may be added to produce an overall score of QL. Although a single, collective figure describing the overall QL of a person may be attractive it does not take into account the relative significance of individual questions. Are a pain-free postoperative cough and the normal performance of activities of daily living equally important? A better way to produce a cumulative score is to deduce the relative importance (weighting) of each question with respect to the ideal outcome which is reflected by the sum of the weighted variables. A third option, favoured by the majority of investigators, avoids the formation of a single overall score and instead adds scores for related dimensions.

Instrument Evaluation

Acceptability

The questionnaire should be capable of being completed in a time frame complying with the clinical situation of the respective patients. It should be easy to un-

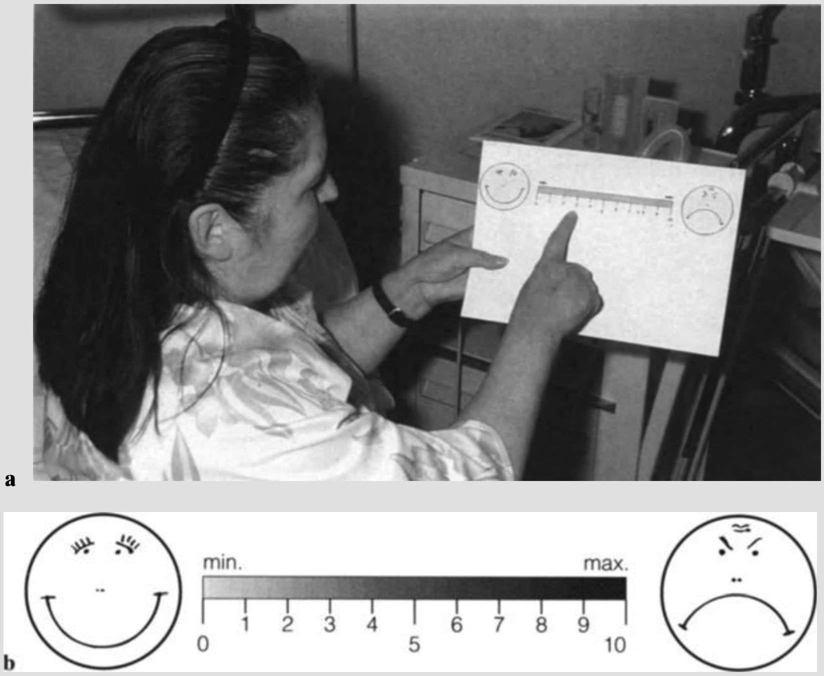

Fig. 26.1. **a** Bedside assessment of pain at rest during the last 24 h in a patient who has undergone laparoscopic cholecystectomy, utilizing a 10-point Likert scale. **b** Total absence of pain and maximum conceivable pain are represented by easy to understand images. The patient indicates or marks his or her response to the given question on the hatched line

derstand and free of intellectual jargon. In the case of significant intra- or postoperative complications a reduced response rate or incomplete answering will be inevitable.

Objectivity

The same results should be obtained independent of the person conducting the testing. Subconscious behaviour or overt positive stimuli from the staff during testing may ruin the most elaborate instrument design.

Reliability

The reliability of a test is characterized by the amount of random error associated with its repeated use. With repeated application of the same questionnaire in the same individuals, the degree of reproducibility of the results can be estimated and the degree of reliability assessed.

physical activity

- normal physical activity for me ☐
- mildly reduced physical activity ☐
- moderately reduced physical activity ☐
- severely reduced physical activity ☐
- completely unable to move my body ☐

indicate the statement that describes this aspect of your life during today

Fig. 26.2. In category rating scales verbal discrimination is used to define the current state of health. The distinctions often appear arbitrary and depend upon a common understanding of verbal nuances to yield valid results

Validity

The criterion "test validity" is the most important quality denominator of a scientific test. The validity of a test is indicated by its ability to actually measure what it claims to measure. The lack of a "gold standard" in QL research renders the assessment of the validity of a new measurement difficult, as no direct comparison is possible. Indirect estimations are attempted by comparing the instrument with other comparable instruments, by comparing items within the instrument to check expected with observed correlations and by assessing the correlation of the results with clinical changes, a characteristic generally referred to as *construct validity.* Consensus approval by a team of experts on the ability of the measure to cover the dimensions of interest and the applicability for such a purpose, a more simple and less mathematically orientated approach, is called *content* or *face validity.*

Sensitivity

A highly sensitive test detects small changes in the clinical course or between different subgroups of patients.

Analysis of Pain and Mobility After Laparoscopic Cholecystectomy

Study Design

Today with the advent of ES, discomfort, disability and dissatisfaction seem to have become the most relevant study endpoints in the surgical treatment of symptomatic gallstone disease. In theory, reduced incisional, retraction and target tissue trauma should result in less postoperative pain and a higher level of mobility. The effect of different physical exercises and provocation manoeuvres on pain and mobility was studied prospectively on the first, second and third postoperative days in 100 patients operated on by laparoscopic cholecystectomy at the Department of General Surgery, University of Tübingen, FRG.

Pain was evaluated by means of a 10-point Likert scale, firstly at rest, then after flexion of the abdominal muscles during five standardized exercise tests and finally after maximal coughing. Mobility during the provocation tests was scored by the examiner according to preset criteria with a maximum of 3 points.

The vital capacity was assessed preoperatively and in the early postoperative period by means of a disposable incentive spirometer device.

In order to detect single factors influencing postoperative outcome a detailed preoperative history and physical workup was conducted. Detailed intraoperative documentation served to correlate outcome data with intraoperative findings, surgical technique and equipment, complications etc. Analysis of the postoperative course, especially analgesic consumption, served as control parameters. The degree of satisfaction with the operation and cosmetic outcome was noted during the first postoperative clinic visit 2 weeks after discharge.

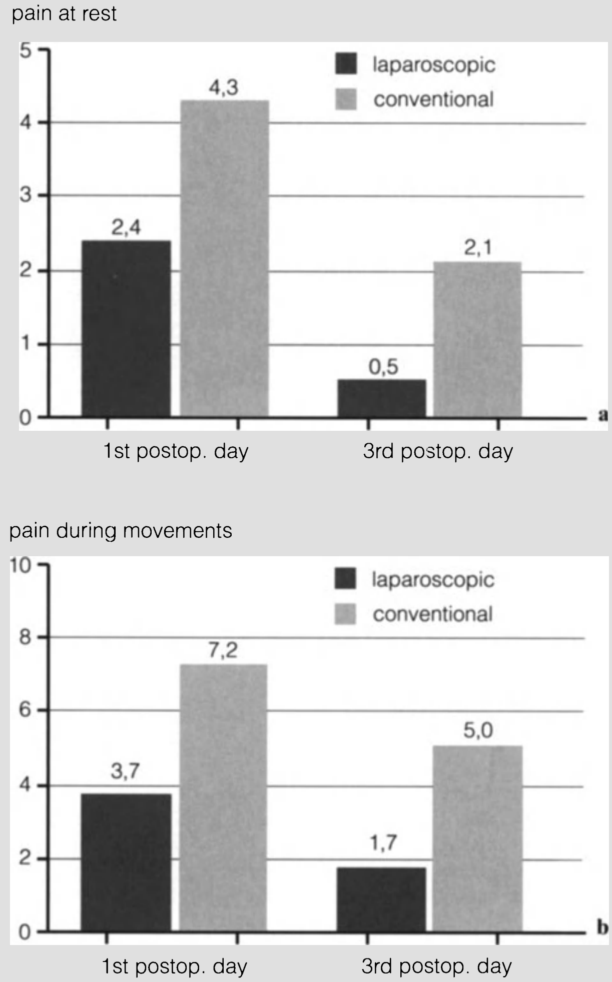

Fig. 26.3. **a** Pain at rest and **b** pain during movements on the first and third postoperative days after laparoscopic cholecystectomy (n=100) and conventional cholecystectomy. Pain was assessed using a 10-point Likert scale. The results indicate significantly reduced intraoperative trauma during laparoscopic cholecystectomy

Results

When comparing laparoscopic cholecystectomy (LC) with open cholecystectomy (OC) in patients with comparable indications for surgery (no acute cholecystitis), the respective scores (pain at rest and during provocation, combined mobility) point to a lesser invasiveness of LC (Figs. 26.3, 26.4).

In the LC group men perceived (stated) less pain at rest, during provocation and during deep inspiration than women, although the mobility scores showed no significant difference between the two groups. Interestingly, overweight women [weight (kg) greater than height (cm)–100+10%] experienced less pain at rest

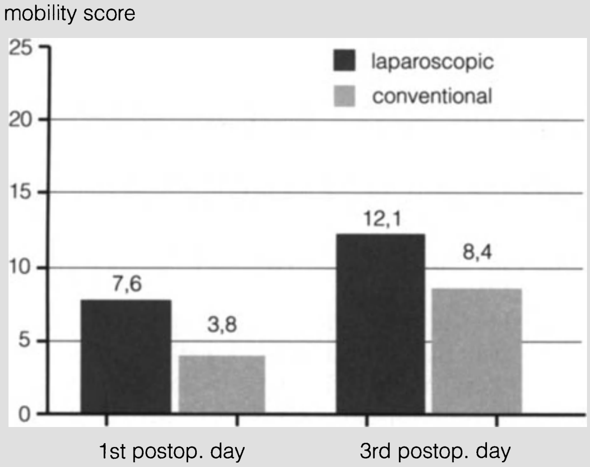

Fig. 26.4. Mobility after laparoscopic and conventional cholecystectomy. In the laparoscopic group patients scored 12 out of a possible 25 points on the third postoperative day, indicating a fast return to activities of daily living

and during provocation than their normal-weight counterparts. The same phenomenon was seen in the men, pointing to the influence of factors in the genesis of postoperative pain other than thickness of abdominal wall alone.

In 64 % of our patients the umbilical incision measured 10 mm. Pain and mobility scores were better in this subgroup than in those patients where the incision was greater than 10 mm, indicating that length of skin incision is a major factor in determining postoperative pain and mobility.

Some 61 % of patients did not receive analgesics after the day of operation. On the first, second and third postoperative days, the remaining 39 % of patients who did receive analgesics beyond the day of operation had more pain at rest and during provocation. This correlation between pain medication and our simple and quick bedside test underlines the validity of the utilized measure. In patients with a pain-aggravating complication (e. g. pneumonia, wound infection or complications necessitating relaparotomy), pain score at rest on postoperative day 1 was always greater than 5, compared with less than 2 in patients without complications; our experience therefore indicates that a pain score of 5 or greater represents a situation when the surgeon should aggressively pursue diagnostic procedures.

It could be shown that indeed laparoscopic cholecystectomy seems to be a less painful procedure, resulting in a greater degree of mobility in the immediate postoperative period. A larger open cholecystectomy control group should allow us to confirm these preliminary results in the near future.

Conclusion

When dealing with QL, conceptual, methodological and practical problems have to be solved. QL represents a rather vague and abstract concept that needs to be defined and broken down into its many dimensions and subdimensions before measurement of these different components can be attempted. Methodologically, scientific instruments have to be selected, developed and tested for their acceptability, objectivity, reliability, validity and sensitivity. Practically, data gathering and retrieval as well as the organizational infrastructure need to be established and maintained.

With increasing application of endoscopic surgery procedures, traditional ways of assessing the success of a surgical intervention will fall short and "success" will take on new meaning with the implementation of quality of life parameters. A new approach to assessing the patient's pre- and postoperative state of health is needed to guide future recommendations on surgical treatment. The measure of quality-adjusted life years is a promising aid in the evaluation of cost efficacy and in decisions on allocation of health care resources.

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27 Future Advances in Endoscopic Surgery

A. CUSCHIERI and G. BUESS

Introduction

There can be little doubt that many aspects of the current technology and instrumentation can and will be improved in the near future, thereby increasing the ease of performance and scope of ES. Whereas in some instances these developments will consist of refinements of existing equipment, newer emerging technologies, in some instances computer assisted, and alternative materials to stainless steel for instrumentation will be employed. This concluding chapter addresses some of these developments. The account, though predictive, is realistic and deals mainly with aspects on which the two departments in Dundee and Tübingen have invested research endeavour and resources collectively and in association with a number of research institutes and specific industrial corporations. In this respect, the active collaboration between surgical science and industry is crucial to the continued advance of the new approach.

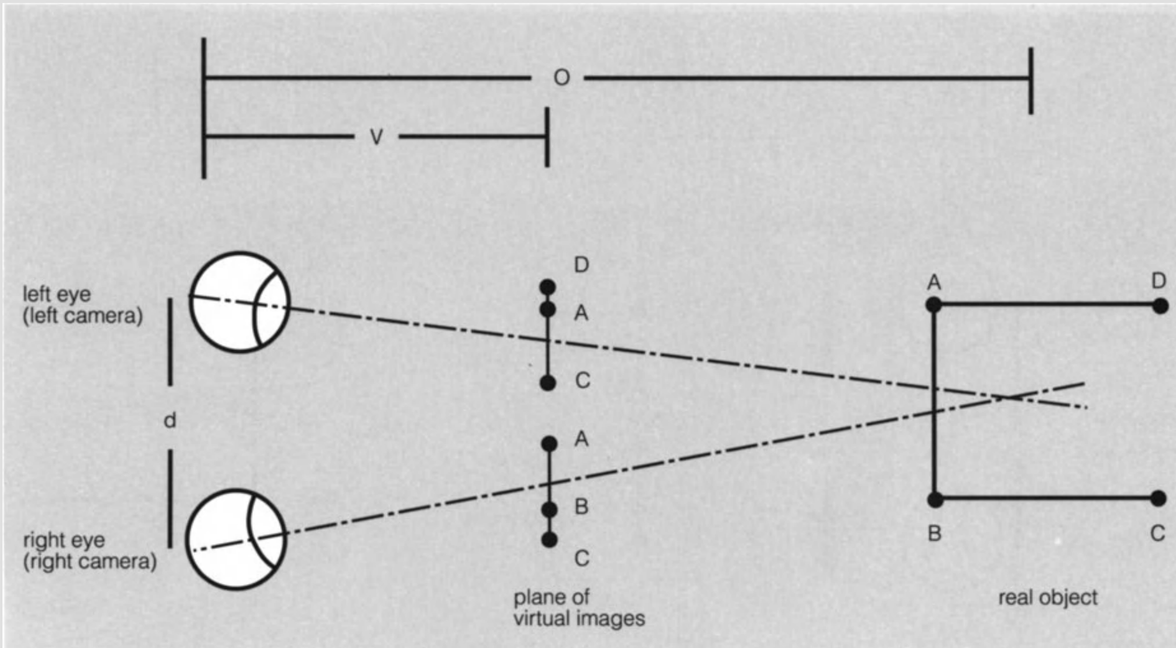
Stereoscopic Vision[1]

The present television/charge-coupled devise (CCD) camera imaging system has two major drawbacks. The most important is the two-dimensional (2D) representation of the three-dimensional (3D) anatomy. This causes problems with hand-to-eye coordination and depth perception. The introduction of a 3D television system will obviate these problems. Studies in the industrial field have shown that the task efficiency measured by the time required to complete the task (e.g. release of hydraulic connectors) is improved substantially when a 3D visual system is used instead of the conventional 2D television imaging. Figure 27.1 describes the 3D generation in normal viewing by the oculocerebral system. The two eyes produce images of the real object from different angles due to the interocular distance. The contour information AD and BC of the visual images of the object produced by the left and right eyes, respectively, are relayed to the cerebral cortex where the 3D image is generated. When the eyes are focussed on a particular object, the angle of convergence results in different degrees of contraction of the ocular muscles. Afferent signals relaying this activity are interpreted by the cerebral cortex as a measure of the distance.

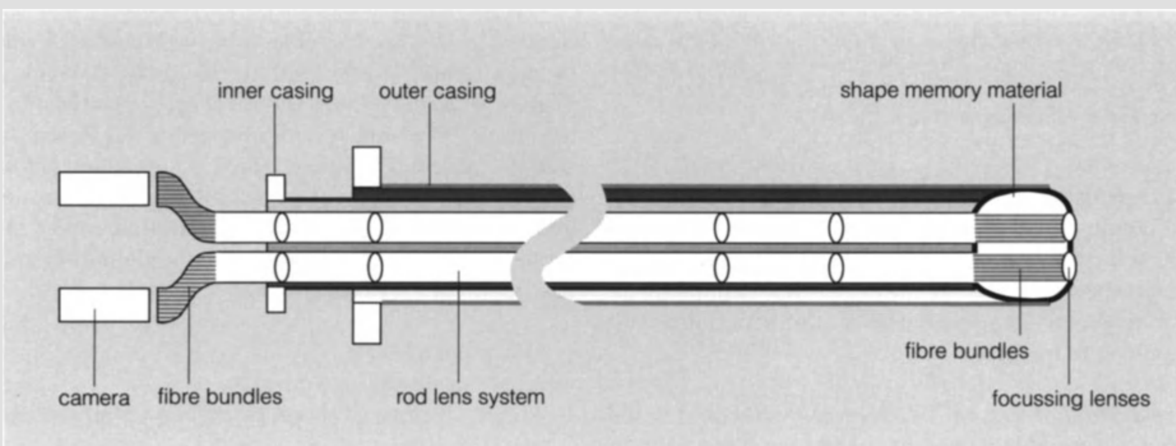
Within the context of endoscopic 3D, there are a number of possible avenues which are currently being researched. The generation of 3D images entails the necessity of obtaining at least two, non-identical images of the object. These pictures can be derived by an imaging system comprising two lenses with a side-by-side location, or one lens that is moved backwards and forwards, or one lens that is focussed sequentially on longer and shorter distances. Irrespective of how the two images of the same anatomical field are obtained, they require processing by computer or dedicated electronics into complementary images that refer to the same object at a particular time but viewed from two spatially distinct positions. Schemes can be designed and developed for both the dual-lens camera and single-lens camera systems.

In the case of the dual-lens system, this is essentially straightforward and is currently available for industrial use with systems for endoscopy being developed in Karlsruhe, Dundee/St. Andrews and other centres. A possible configuration for such an endo-3D-visual system is illustrated in Fig. 27.2 where two CCD cameras are employed. In this instance, the television monitor serves as the medium for the projection of the virtual images being recorded by the two cameras with sequential display of left and right eye information (Fig. 27.3). In essence, the television monitor functions as the plane of the two images. An optical high-speed shutter synchronized with the sequentially displayed right and left images is placed in front of each eye, thereby providing the correct image for the correct eye in the appropriate time frame. This is the standard on supervision for remote handling.

[1] The following section was written by H. Becker, H. Rininsland, and R. Trapp, Nuclear Development Center, Karlsruhe, FRG.



27.1



27.2

Fig. 27.1. Generation of 3D imaging by the oculocerebral system. The two eyes produce images of the real object from different angles due to the interocular distance

Fig. 27.2. Schematic configuration of twin-camera dual-lens endoscopic 3D television imaging system

Other possibilities exist where one camera is used to obtain different virtual images from rapidly shuttered image information from the dual-lens system. The key requirement for the dual-lens binocular scheme is the optical alignment of the two lenses with known precise spacing with the capability of synchronous precise focussing at the same point in space. To provide the necessary separation and coordinated movement of the two lenses, shape-memory materials (see below) may be needed to ensure precise and reproducible synchronous movement. For single-lens systems, the object would have to be computer modelled and then two separate images built up from this model.

In endoscopic work, some of the major technical problems are due to the difficulties of matching image transmission through the optics with the video techniques. In this respect three options are available:

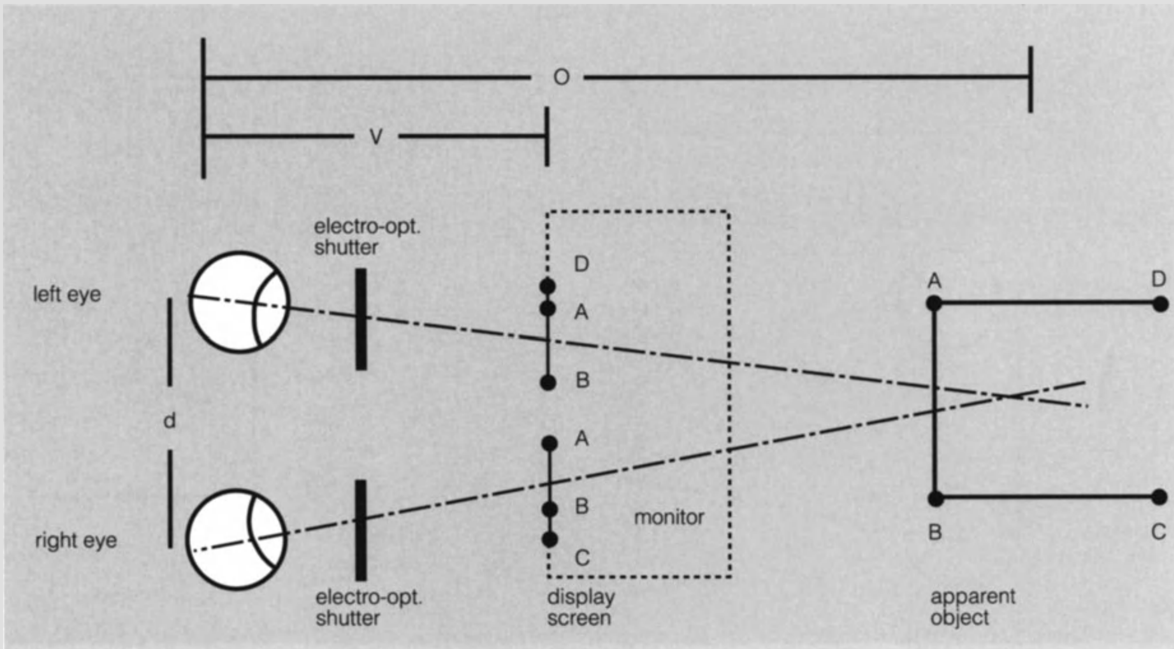


Fig. 27.3. Sequential display: in this instance, the TV monitor serves as the medium for the projection of the virtual images being recorded by the two cameras with sequential display of left- and right-eye information (100 or 120 Hz)

Anaglyphs. These provide simultaneous presentation of colour-coded (red/green) left and right images on the television screen. Colour filters are used to present the respective image to each eye. This technology induces severe oculo-cerebral strain, especially with non-colour images.

Dual-Monitor System. Two televison screens are used to generate a dedicated image for the left and right eye, respectively. Both screens are placed at an angle of 90°. A half-silvered mirror is used to combine the two images, each being polarized differently by means of filters in front of the screen. Glasses with the respective polarization filters finally channel the images to the respective eyes.

The dual monitor system is a solution with several disadvantages. Only one person can use the system at any one time, and the technology dictates that the image will be correct observed at only one viewing point, head movement strongly restricted. Needless to say, a pair of monitors – with equal quality – is required. Finally, repeated adjustments of the mechanical arrangement and optical axes are needed and projection onto the wall is not possible.

Sequential Display. Developed by the Nuclear Development Centre (Karlsruhe) in 1986–1987, sequential display with a high-speed shutter (Fig. 27.3) is the most advanced 3D vision system now available. Research into the system technology of remote handling led to the conclusion that no stereoscopic video system was available that satisfied the special requirements of remote supervision. This resulted in the definition and realization of a system providing the operator with:

- Maximum mobility
- A technically optimal image
- Above all close adaption to human visual perception.

The essential characteristics of the systems are:

- Media independent (monitor, projection)
- Minimum of inherent maping errors
- Fully colour applicable
- Daylight use
- Free of flicker (100 or 120 Hz)
- Shutter glasses infrared controlled

Shape Memory Metals and Instrumentation[2]

A unique group of metals which exhibit shape memory have useful biomedical applications and are particularly relevant to the development of instrumentation for ES. Under specific conditions, these shape memory alloys have the ability to substantially recover their original shapes, even if they have been greatly deformed.

The original shape of a device made of a shape memory alloy is determined during a special metallurgical treatment process.

Alloys which are capable of transforming reversibly between martensitic and austenitic crystalline structures are able to exhibit a shape memory effect. The phase in which an alloy consists of substantially a pure austenitic structure can be called the *austenitic phase.* The phase in which the alloy contains substantial amounts of the martensitic crystalline structure may be called the *martensitic phase.* In the austentic phase, the alloy is relatively stiff. In contrast, when a transformation of at least some of the alloy to the martensitic phase occurs, the alloy becomes relatively malleable.

The transformation from the austenitic phase to the martensitic phase can occur either with a temperature change or with the application of external stress. Reversal of the temperature change or removal of the externally applied stress causes the martensite that has formed to change back to the austenitic phase. Deformation which was applied to the alloy while it was in the martensitic phase will reverse itself so that the alloy will substantially return to its original shape.

Thermal Shape Memory

Thermally activated shape recovery of shape memory alloys will be discussed first. As can be seen in Fig. 27.4, a shape memory alloy which is in the low-temperature martensitic phase will begin to transform towards the higher-temperature austenitic phase when its temperature rises above A_s. The transformation will be complete when the temperature rises above A_f. The actual values of A_s and A_f depend on the composition of the alloy and its prior metallurgical history. These values can be adjusted such that they fall in the range of body temperature. The reverse transformation will begin

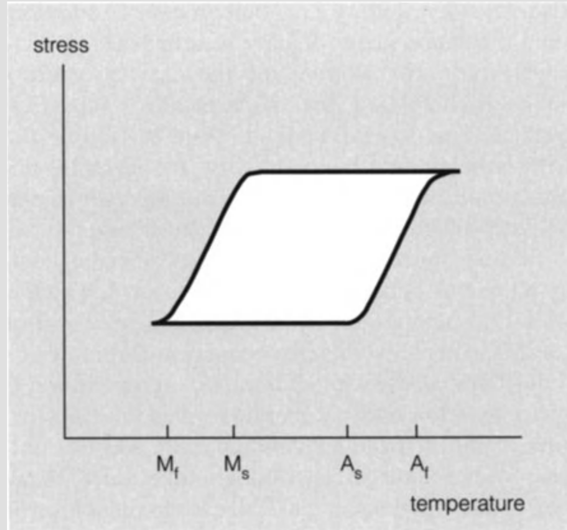


Fig. 27.4. The temperatures M_s, M_f, A_s and A_f define the thermal transformation hysteresis loop of the shape memory alloy

when the temperature drops below M_s and will be complete when the temperature drops below M_f. The temperatures M_s, M_f, A_s and A_f define the thermal transformation hysteresis loop of the shape memory alloy which is shown in diagrammatic form in Fig. 27.4.

When a shape memory alloy has an A_s which is slightly above body temperature, a device such as a bone plate or stent may be in its martensitic phase at body temperature. This device will therefore be in a relatively malleable state when it is at body temperature. The device may be deformed and then inserted into the body. Once in place, the device may be heated by any suitable means. For example, heat may be applied with a warm fluid or by passing electricity through it. When the temperature of the shape memory alloy exceeds A_s (for instance, above 40 °C), the device will recover towards its original shape. This tendency to recover will be complete when the temperature reaches A_f (for instance 50 °C), at which point the shape memory alloy will be in its austenitic phase. In the case of a bone plate, this recovery can be used to compress a fracture site if the plate has been stretched longitudinally while it was in its martensitic phase prior to placement across the fracture. In the case of a stent, the deformed state can be utilized to place the stent into the appropriate area with the assistance of a catheter. The shape recovery which occurs with increasing temperature then permits the stent to expand radially against the walls of the vessel to keep it patent.

In the cases just described, A_s was chosen to be slightly above body temperature. This has the dis-

[2] This section was written by W. R. Pyka, L. M. Middleman, and P. P. Poncet.

advantage of requiring a heating process. In addition, when the shape memory alloy returns back to body temperature after heating and the recovery process has been completed, the shape memory alloy may reach M_s. This depends upon the hysteresis loop of the material being used, but risks the device becoming relatively malleable again. This may not represent a major disadvantage, but is not ideal in clinical use.

To overcome these disadvantages, the shape memory alloy may be treated so that it has an A_s which is below body temperature. In this case, the device will at least begin to recover its shape and transform towards its austenitic phase when it is at body temperature. If A_f is at or below body temperature, then this transformation, and hence the shape recovery, will be complete when the device is at body temperature. However, in order to deform the device for implantation, it must be kept below body temperature. The device is then installed in the body while it is kept cold. As soon as the temperature of the device reaches A_s, the shape recovery process begins. If installation required some time, then the device must be kept cold until the position is acceptable. Ideally then, A_s is above freezing, since it would be damaging to the body tissues if the device were kept at temperatures below freezing during installation. Keeping devices such as bone plates and stents below body temperatue during installation would require them to be bathed in cold fluid until they are correctly positioned to permit the shape recovery process to occur.

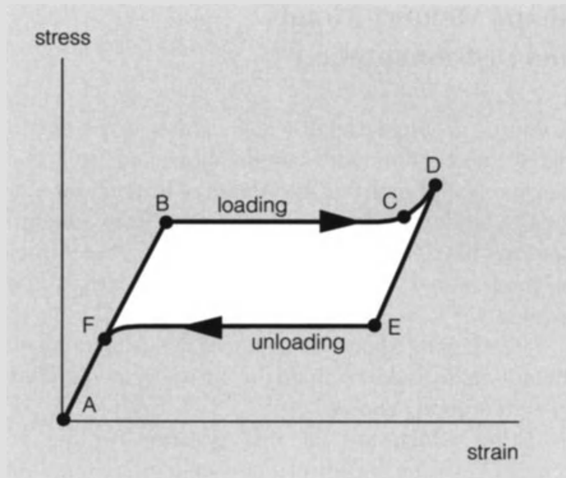


Fig. 27.5. Representative stress-strain diagram of a superelastic shape memory alloy. At point *A*, the alloy is in its austenitic phase. If gentle external stresses are applied to the alloy, it will reach the state represented by point *B*. Stressing the alloy further will induce the formation of martensite along the line between points *B* and *C*. Once the alloy is at point *C*, further stress will only cause deformation within the martensitic phase, as represented by point *D*. When the stress is released, the stress decreases to point *E*, after which the stress-induced martensite changes back to austenite, as described by the *line* between points *E* and *F*. Complete release of the applied stress permits the alloy to return substantially to point *A*

Superelasticity

Under certain conditions, shape memory alloys exhibit superelasticity which does not rely on temperature change in order to accomplish shape change. When a superelastic shape memory alloy is greatly deformed from its original shape, the deformation occurs by a transformation of the original austenitic phase to the martensitic phase. Instead of being induced by a temperature change, the martensitic phase has now been induced by the application of external stress. The martensitic crystalline structure is therefore called stress-induced martensite. When the externally applied stress is removed, the shape memory alloy substantially recovers its original shape by the transformation of the stress-induced martensite back to the austenitic phase. The entire transformation process occurs isothermally.

Figure 27.5 is a representative stress-strain diagram of a superelastic shape memory alloy. At point A, the alloy is in its austenitic phase. If gentle external stresses are applied to the alloy, it will reach the state represented by point B. Stressing the alloy further will induce the formation of martensite along the line between points B and C. Once the alloy is at point C, further stress will only cause deformation within the martensitic phase, as represented by point D. When the stress is released, the stress decrease to point E, after which the stress-induced martensite changes back to austenite, as described by the line between points E and F. Complete release of the applied stress permits the alloy to return substantially to point A.

Superelasticity arises in appropriately treated shape memory alloys while they are in their austenitic phase at a temperature which is greater than A_s and less than M_d, where M_d is the maximal temperature at which the transformation to the martensitic phase can be induced by the application of stress. This temperature at which superelasticity occurs can be adjusted to be in the range of body temperature with metallurgical processing techniques.

A superelastic shape memory alloy is capable of being elastically deformed far beyond the elastic limits of conventional metals. A device which is formed from a shape memory alloy which exhibits superelasticity can be deformed substantially reversibly by 11 % or more. For example, a 1.0-m length of superelastic wire may be stretched to 1.11 m in length, wherin at least a portion of its alloy will undergo a phase change to the martensitic phase with the formation of stress-induced martensite. Upon release of the stress, the wire will return substantially to its 1.0-m length, and its alloy will correspondingly return to the austenitic phase. By way of contrast, a similar wire of spring steel or other conventional metal may only be elastically stretched approximately 1 %, or to 1.01 m in length. Any further stretching of the conventional wire, if not resulting in actual breakage of the wire, will result in a non-elastic (plastic) deformation such that upon release of the stress, the wire will not return to its original length. Superelastic materials may also be bent, twisted and compressed to a far greater degree than conventional metals.

It is believed that the superelastic property is achieved by either twinning or stress-induced phase transformation within the alloy, rather than by dislocations which occur during the plastic deformation of ordinary metals. A superelastic material may therefore be deformed and released thousands of times whithout being subject to breakage due to metal fatigue, which limits the number of deformation cycles which a conventional metal may undergo without failure.

Superelastic shape memory alloys have a special feature which is particularly beneficial for medical applications. As seen in Fig. 27.5, the stress-strain curve presents a plateau between points B and C. This plateau represents the region during which martensite is stress induced. While the alloy undergoes this transformation, it can deform greatly with only minimal increase in loading. Therefore, devices made of superelastic shape memory alloy have a built-in safety feature. These devices can be designed (using appropriately treated alloys and appropriate dimensions) such that when they are loaded beyond a certain amount, they will tend to deform with a concomitant austenite to stress-induced martensite phase change, instead of merely presenting a greater resistance with limited deformation to the load, which is seen with conventional metals.

Just as the stress-strain curves of shape memory alloys present a plateau upon loading, they also present a plateau upon unloading. This is represented by the line E to F in Fig. 27.5. Unloading occurs when a device made of superelastic shape memory alloy is permitted to revert from a significantly deformed shape towards its original unstressed shape. Because of the plateau, such a device can maintain an almost constant force during much of the unloading cycle (line E to F in Fig. 27.5) until just before it is completely unloaded.

An example of a useful application of a superelastic shape memory alloy is in the manufacture of surgical blades, scissors or dissectors. A blade made of superelastic shape memory alloy may be treated such that its original shape is significantly curved. Because of the superelasticity, the blade may be stressed so that it can be passed into a straight narrow cannula. This cannula can be placed into the body through an endoscopic or laparoscopic portal. When the blade is deployed from the end of the cannula, it recovers its original significantly curved shape. The instrument therefore permits remarkably greater access and facilitates dissection. On completion, the curved functional tip is withdrawn back (stressed) into its straight restraining cannula prior to removal through the laparoscopic or endoscopic port.

Composition

The most promising shape memory alloys consist essentially of nickel and titanium, for example, about 50% atomic percent nickel and about 50% atomic percent titanium. Additional elements such as copper, cobalt, vanadium, chromium or iron may be added to affect the mechanical characteristics of the alloy or the temperature at which particular desired thermal shape recovery or superelastic characteristics are obtained. Nickel/titanium alloys have already been utilized in a number of mechanical applications. Devices which depend on thermally activated shape recovery have been implanted in the form of plates, Harrington rods, vena caval filters, vascular stents, bone staples, dental implants and femoral head cups. Devices which utilize superelastic shape memory alloys have been used as temporary dental arch wires and localization needles for subclinical breast lesions, as well as for permanently implanted anchors for suturing tendinous or capsular structures to bone. No adverse biological effects from the metal itself have been reported.

Endoscopic Retraction

Currently exposure of the operative field in endoscopic surgery relies on adequate insufflation with CO_2, positioning of the operating table and the use of graspers to lift and tent structures being dissected. These manoeuvres result in a restricted exposure, decrease the task efficiency and add to the difficulty in

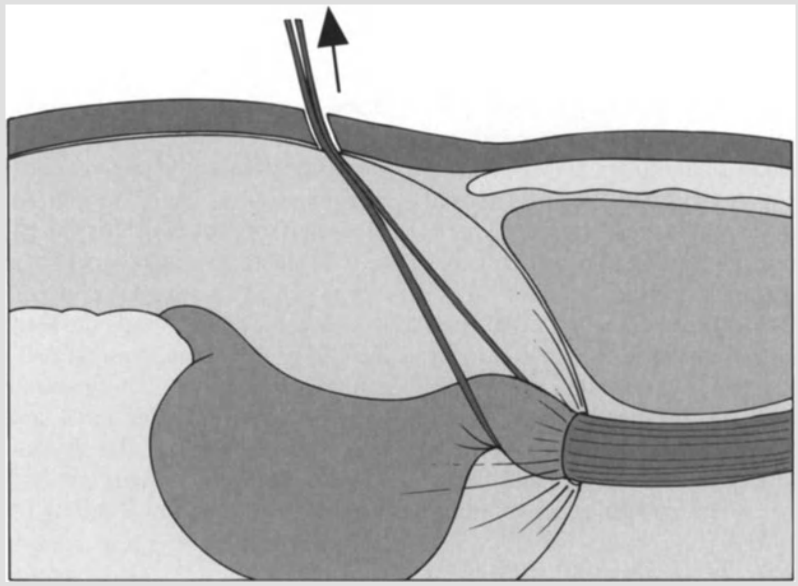


Fig. 27.6. Sling lift

the execution of the procedure. There is little doubt that better techniques of endoscopic retraction are needed to increase the scope and safety of ES, particularly within the peritoneal cavity. We have been involved in research in this area and have pursued this activity along several lines.

Sling Lifts

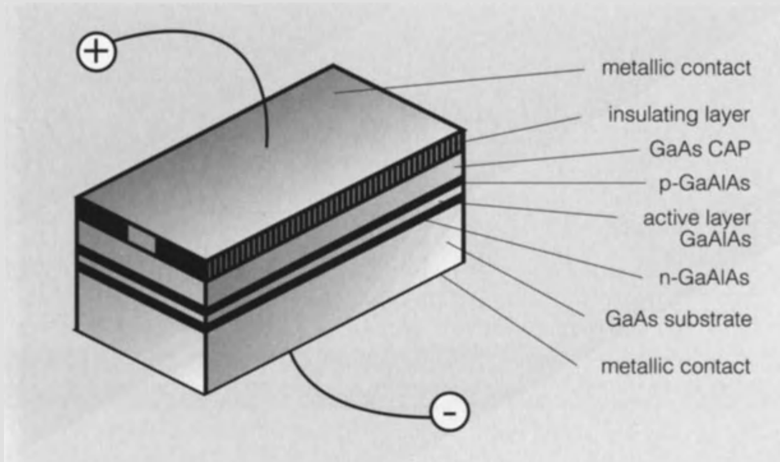
This concept relies on the use of the parieties, anterior abdominal wall or thoracic cage, to hitch up organs during dissection and mobilization. The method involves the insertion of silicon slings through the anterior abdominal wall or thoracic cage, passage of the sling around the organ and then exteriorization of the sling, the two external ends of which are then pulled and held on traction by an artery forceps close to the skin (Fig. 27.6). We have found the technique to be useful in subdiaphragmatic surgery of the oesophagus, e. g. ligamentum teres cardiopexy and cardiomyotomy where the lifting up of the gastro-oesophageal junction towards the anterior abdominal wall greatly facilitates the posterior dissection of the oesophagus. The technique is essential for the mobilization of the oesophagus during thoracoscopic oesophagectomy performed through the right chest. The sling-lift technique needs further development in respect of suitable variable curvature (superelastic) passers which will facilitate the passage of the silicon slings around the relevant organ.

Dipping Endoretractor

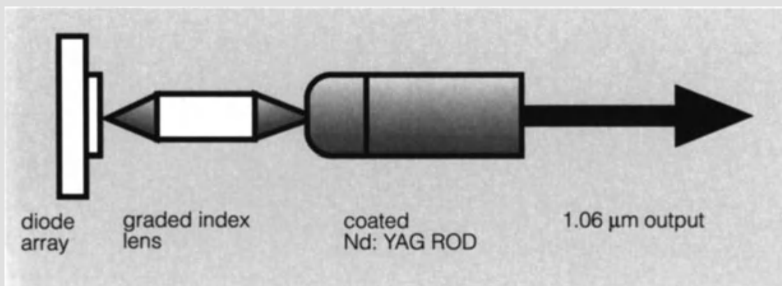
The basic design of the prototype of the dipping endoretractor which is currently under evaluation in Dundee is shown in Fig. 23.5. The endoretractor fits inside an 11.0-mm cannula and operates only with a 30° forward-oblique optic. The dipping bar ahead of the optic retracts tissues ahead of the operative field, and the superior surface of the long segment is used to lift up organs such as the liver from the operative field. The dipping endoretractor is particularly useful in laparoscopic biliary surgery, especially in patients with a floppy quadrate lobe. We have also found it useful in subdiaphragmatic oesophageal surgery where it gives unparalleled exposure of the hiatus and abdominal oesophagus.

Solid-State Diode Lasers

At present large frame ion and arc lamp-pumped lasers have major drawbacks in that they are expensive, inefficient, non-tunable and generally require major service inputs such as three-phase electrical supplies and high-volume flow-rate cooling. All these



27.7



27.8

Fig. 27.7. Composition of single-stripe GaAlAs laser diode

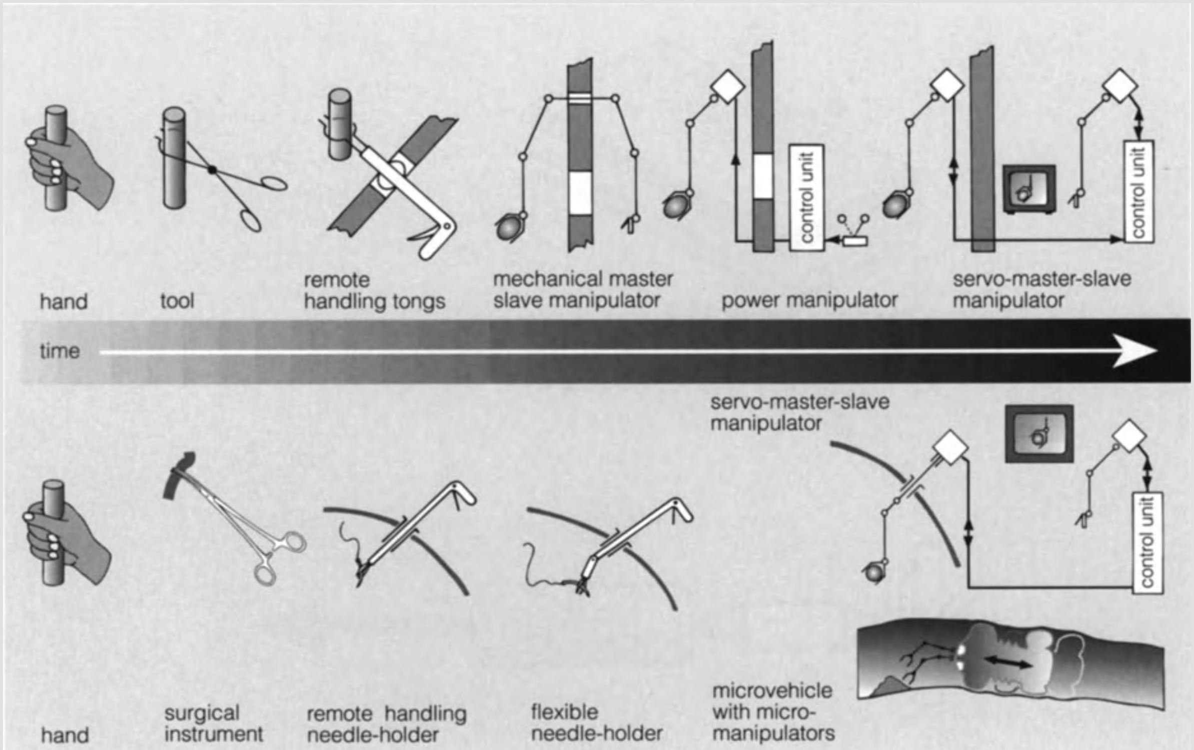
Fig. 27.8. A monolithic diode laser-pumped Nd:YAG laser. The 809 radiation from the laser is coupled into the Nd:YAG crystal via a graded index lens. The Nd:YAG cavity is entirely in the crystal, with dielectric mirrors deposited directly onto the crystal faces

lasers depend on gas discharge as the power source. Thus in CO_2 lasers the discharge excites the lasing medium directly, whereas in Nd:YAG, a gas discharge in the flashlamp optically pumps the lasing ions. It is the reliance on gas discharge technology which limits the performance of these lasers with respect to maintenance-free function and efficiency. Dye lasers, although tunable, suffer complications associated with flowing liquid media which often involve toxic dyes and solvents. *There is therefore a need to substitute these systems with efficient hand-held portable all-solid-state lasers.*

Recent developments in diode laser technology has led to the production of semiconductor diode lasers with continuous-wave (cw) output powers of up to 38 W and lifetimes of tens of thousands of hours. The basic configuration of a single-stripe GaAlAs laser diode is shown in Fig. 27.7. The maximal specified power from such a device is 5 W. The power output can be increased by the construction of phased arrays of these diode strips which, by being sufficiently close to one another, result in overlap of the optical fields and lead to a degree of phase-locking amongst the strips. These GaAlAs diode lasers have been used to pump materials such as Nd:YAG, thus constituting an entirely solid-state system or holosteric laser (Fig. 27.8).

Whilst most of the holosteric laser work has been concentrated on Nd:YAG, other materials are suitable for diode laser pumping, e.g. Nd-doped glass, YLF, vanadate, non-linear crystals, etc. The diode-pumped holmium laser, emitting at 2 µm, has important applications in surgery due to its strong absorption in water.

Non-linear optical techniques are attractive in connection with these lasers due to the high-quality beams which allow efficient generation of new wavelengths industry (manipulators)



endoscopic surgery

Fig. 27.9. Development of remote-handling technology in industry and ES

(by frequency doubling) in non-linear crystals such as potassium titanyl phosphate. The tunability of these portable diode lasers can be extended even further by the use of crystals such as urea and beta-barium borate which act as opical parametric oscillators. These crystals can subdivide incident photon energies into photons having lower energies (longer wavelengths).

Development of Remote-Handling Technology[3]

Nuclear technology, because of its hazardous nature, provided the main impetus for the development of remote-handling technology. These devices were first used in the United States to enable safe handling of radioactive materials. Currently application of remote-handling systems has been broadened to other activities, e.g. conventional industry (foundry, forge), subaqua technology, medicine, explosive ordinance disposal and space technology.

During the last 40 years, the *manipulator* has been developed from a fairly simple mechanical device to a highly sophisticated system which is computer assisted. The *manipulator* is normally guided and controlled by an operator and employed for different and variable tasks. In this respect, it must be differentiated from a *robot* which is normally used for identical repetitive manipulations, e.g. industrial robots in assembly-line production.

The various components of a remote-handling system are outlined in Fig. 27.9. They form the basis for the development of instrument and systems for ES since this entails complicated remote manipulations. At present, the following types of remote-handling equipment can be distinguished:

[3] The following section was written by H. Rininsland, R. Trapp and H. Becker.

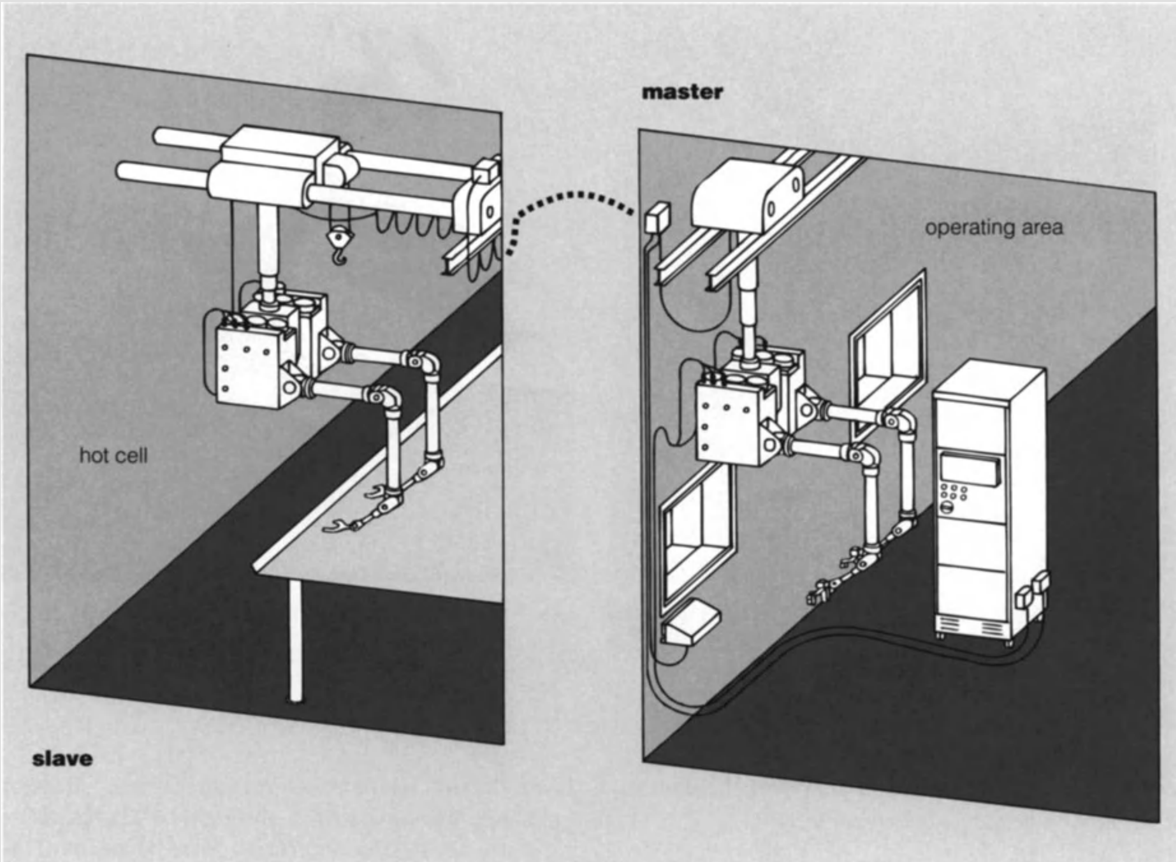


Fig. 27.10. Master-slave manipulator in a hot cell with shielding windows

1. Remote-handling tongs
2. Mechanical parallel manipulator
3. Power manipulator
4. Servo-master-slave manipulator

Remote-Handling Tongs. These are simple mechanical devices used for the transmission of manual forces. They may be rigid or pivoted. Their working volume is very small, and their applicability is hampered by their limited mobility.

Mechanical Master-Slave or Parallel Manipulators. These are also used to transmit manual forces. Compared to the remote-handling tongs, they have a higher mobility due to seven degrees of freedom (movement) which enable them to perform complicated laboratory work. They consist of three main components: the master arm, a through tube or connecting element, and the slave arm (Figs. 27.9, 27.10). The slave arm follows exactly the movements of the master arm which is guided by the operator. As a rule, they are employed in pairs as the main remote-handling equipment in hot cells.

Power Manipulator. This is normally switch- or joy stick-controlled and is driven by electric motors. The complete unit consists of an arm and a mounting arrangement to move the arm to the next place (Figs. 27.9, 27.11). The arm has one to three pivots which allow between four and eight movements. The standard arm designs have five movements: shoulder rotation, shoulder pivot, elbow pivot, wrist rotation and gripping. Depending on the design, power manipulators can be made to lift objects weighing up to several tons. Power manipulators offer the advantages of mobility, high load capacity and unlimited turning capability of the tong. Their major drawback is low work speed because the operator cannot coordinate

Fig. 27.11. Master-slave manipulator in a hot cell

Fig. 27.12. Vehicle with power manipulator

several movements at once, and therefore these movements have to be carried out sequentially.

Servo-Master-Slave Manipulator. This combines the good qualities of the mechanical master-slave and of the power manipulator. It offers the combination of high sensitivity, force amplification and accurate positioning. As distinct from the mechanical master slave and the power manipulator, the mechanical power transmission elements between the master and slave arm are replaced by electric or electrohydraulic systems. The two arms (master and slave) form a bilateral algorithm. In addition to the high positioning accuracy, this control system allows a force reflection such that the operator has a good feedback of what he/she is doing.

Digital control with a computerized system where the functions are software driven enhances the scope and flexibility regarding the number of tasks, algorithms and mode/sequences. The operator can limit his/her activity to commands and data input in detailed or general format (depending on the capability of the system) and to monitoring the execution of the intended task. This can be obtained by fixed programs or by "teach and repeat" operations, i. e. master-slave mode, robot mode and the mixed mode. Immediate transition from one mode to another is possible. In practice, the operator guides the manipulator and performs the task by the slave arm under visual television guidance. The slave arm is observed by the television camera while the master arm is guided by means of the pictures on the television screen. The operator can reduce the interactions to a minimum using a speech-interface or a touch screen. Owing to the high accuracy and sensitivity, very complicated manipulations can be performed, e. g. free-hand welding, bomb disposal, connecting and disconnecting of pipe systems, etc. In addition, computer-aided operation provides the possibility of diagnosis and supervision of security and safety, e. g. collision avoidance.

The master-slave manipulator can be attached to a carrier system such as vehicle (Fig. 27.12) or a crane which is also guided by remote control. Equipped with sensor system and appropriate software and a computer, such an assembly can operate semi-autonomously, albeit supervised by the operator. Further research and development is in progress, designed to improve the autonomous operation mode.

Application to ES

The present generation of instruments used in ES corresponds to the remote-handling tongs used in the nuclear industry in the early 1950s. Furthermore, the operative manipulations are performed at a distance from the operative field which is viewed across a television screen. The current surgical instruments have only limited mobility. Suturing is, for this reason, difficult because the angle of the needle when grasped by the holder cannot be altered with ease (Fig. 27.9). This problem would be solved, resulting in the capacity for precise placement of the needle, if a further joint were to be incorporated in the "remote" needle holder. In essence, this modification would correspond to the mechanical master-slave manipulator.

Sophisticated power manipulator technology would be needed to produce complex manipulations with the necessary degrees of freedom comparable to the human hand. Such systems would be capable of moving a needle through a complete circle.

Advanced miniaturized manipulators (Fig. 27.9) will considerably improve the steerability of instruments through small stab wounds and therefore enhance the scope and safety of ES. Current research and development in *microtechnology* is promising, and there are good prospects that micromechanics, microactors, microelectronics and microsensors will lead to the design and construction of microsystems with sophisticated capabilities, such as microvehicles (Fig. 27.9) equipped with micromanipulators, viewing systems and sensors.

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Subject Index